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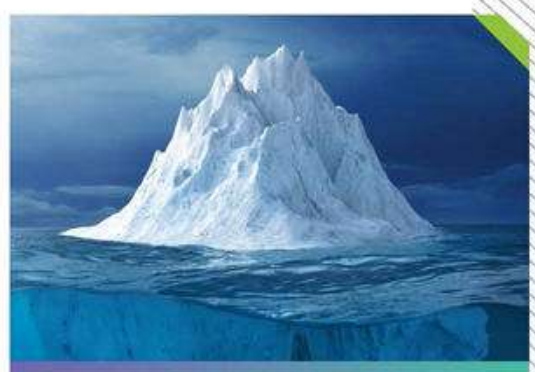

WHERE DO GIANT ICEBERGS COME FROM?

AI

HOW ARTIFICIAL INTELLIGENCE WILL CHANGE OUR LIVES

SMART ASTRONAUT ASSISTANT

DIAGNOSIS WITHOUT DOCTORS

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> "The more information an AI program is fed, the better it understands and grows"

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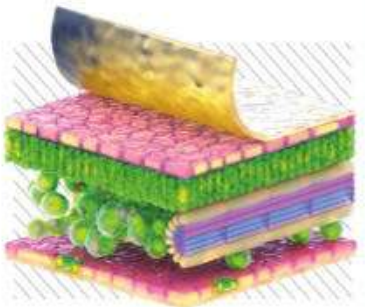

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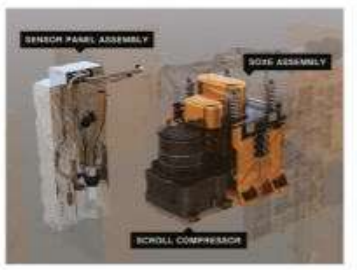

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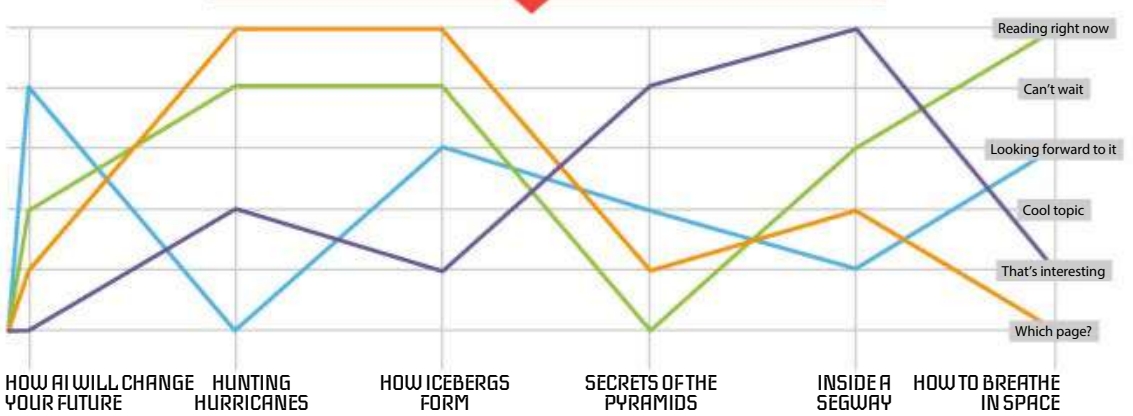
GO TO PAGE 24 FOR GREAT DEALS

Artificial intelligence is an incredible thing to behold, and we're not afraid to admit it's a little bit scary, especially if science fiction's sentient machine future is anything to be believed. In the last couple of decades our journey towards an AI that can solve complex problems as well as exhibit convincing independent thought has developed in leaps and bounds, from the chess-playing supercomputer Deep Blue becoming the first machine to beat a human champion, Garry Kasparov, in 1997 to the freaky world of AI-generated art today. In this issue's cover feature, we explore the fascinating world of smart robots and machines, how they work and how our world could be improved by them. Enjoy!

Ben Biggs
EDITOR

WHAT WE'RE ANTICIPATING



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DR ANDREW MAY
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

LAURA MEARS
Biologist Laura escaped the confines of the lab to the rigours of an office desk as a keen science writer and full-time software engineer.

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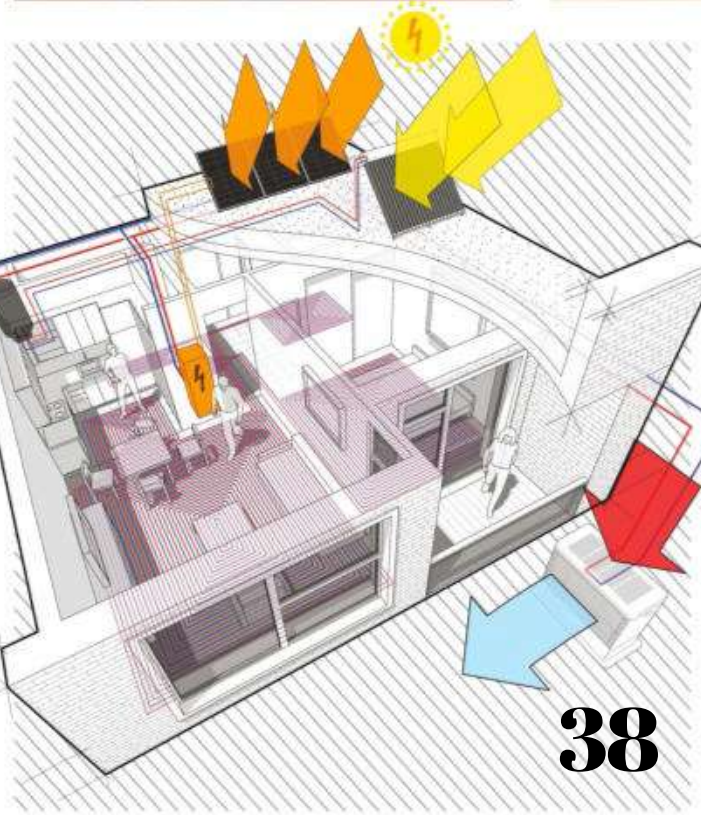
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Red-nosed lanternfly

Although they might not glow like Rudolph's, the noses of lanternflies (*Pyrops karenius*) are just as important for finding food. Found in the forests of Burma, Thailand and India, red-nosed lanternflies have prominent 'noses', or 'snouts', which were once thought to glow at the tip. Though they don't actually glow, those colourful red noses are used to work their way through tree bark and drink the stinky sap.

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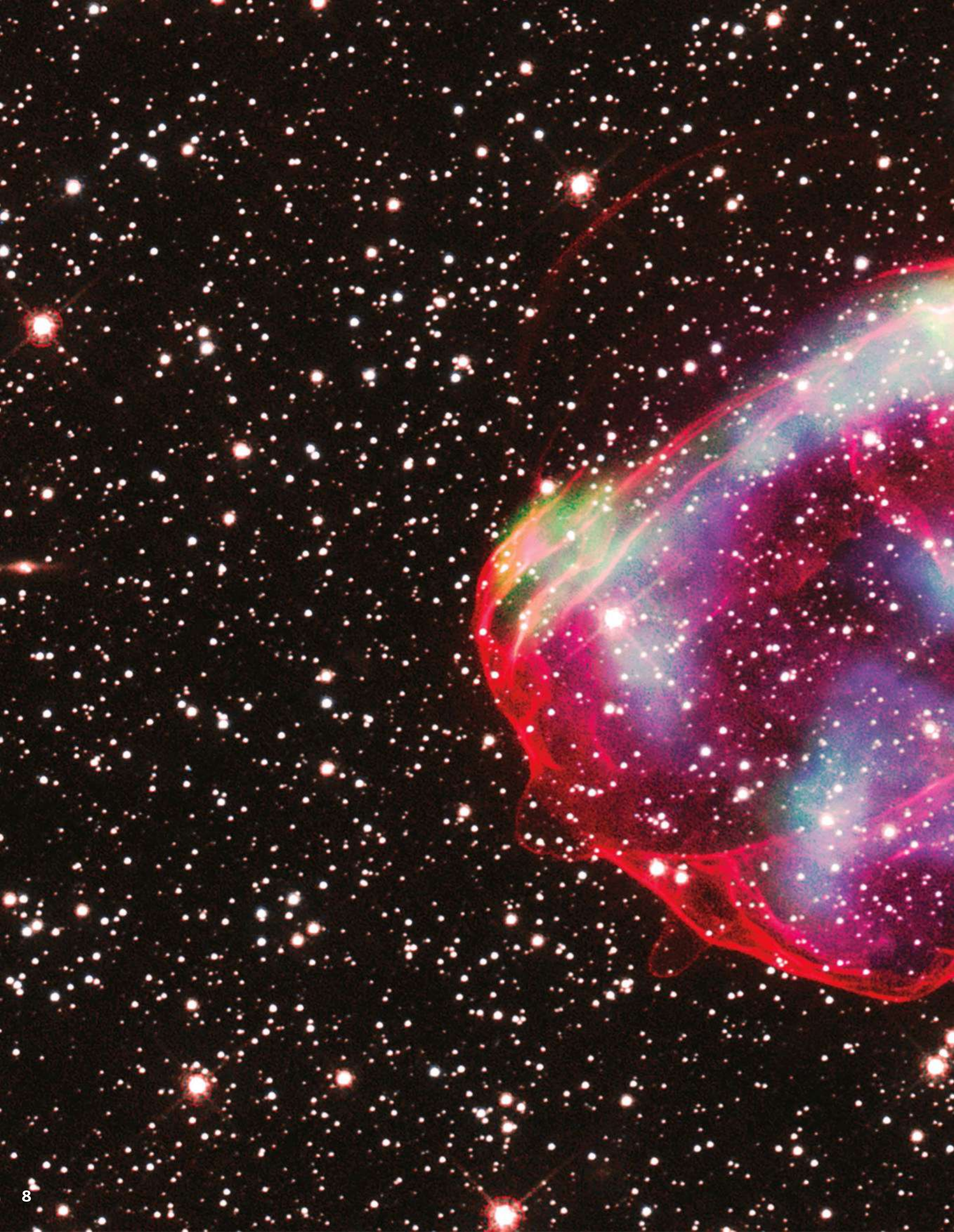

Scarlet supernova

Astronomers have combined optical data from Hubble and X-ray data from the Chandra Observatory to create this composite image of a supernova remnant called SNR 0519. Following the explosion and collapse of a white dwarf star in the Large Magellanic Cloud, around 160,000 light years from Earth, this crimson cloud of cosmic dust and radiation was produced by the supernova.

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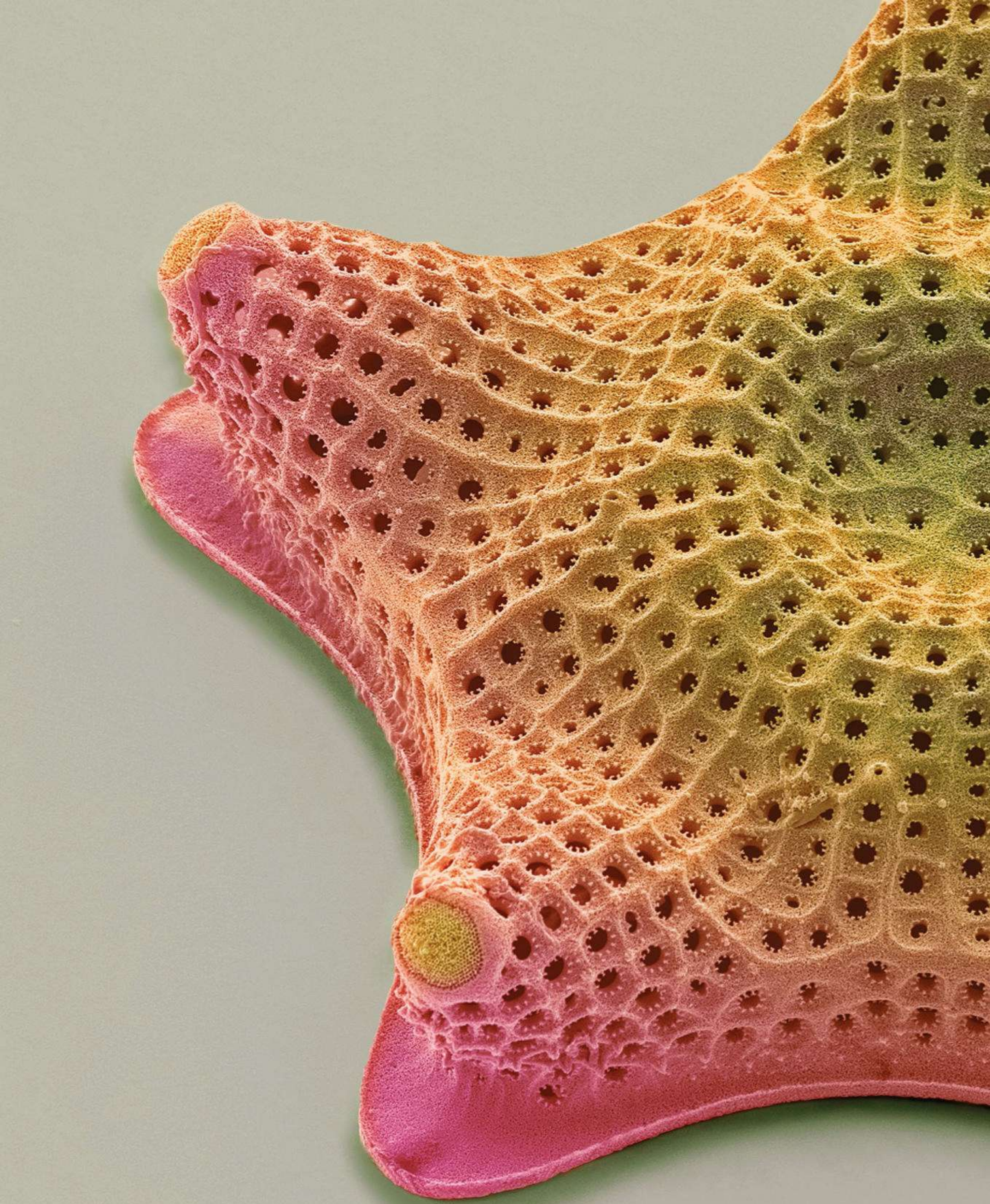

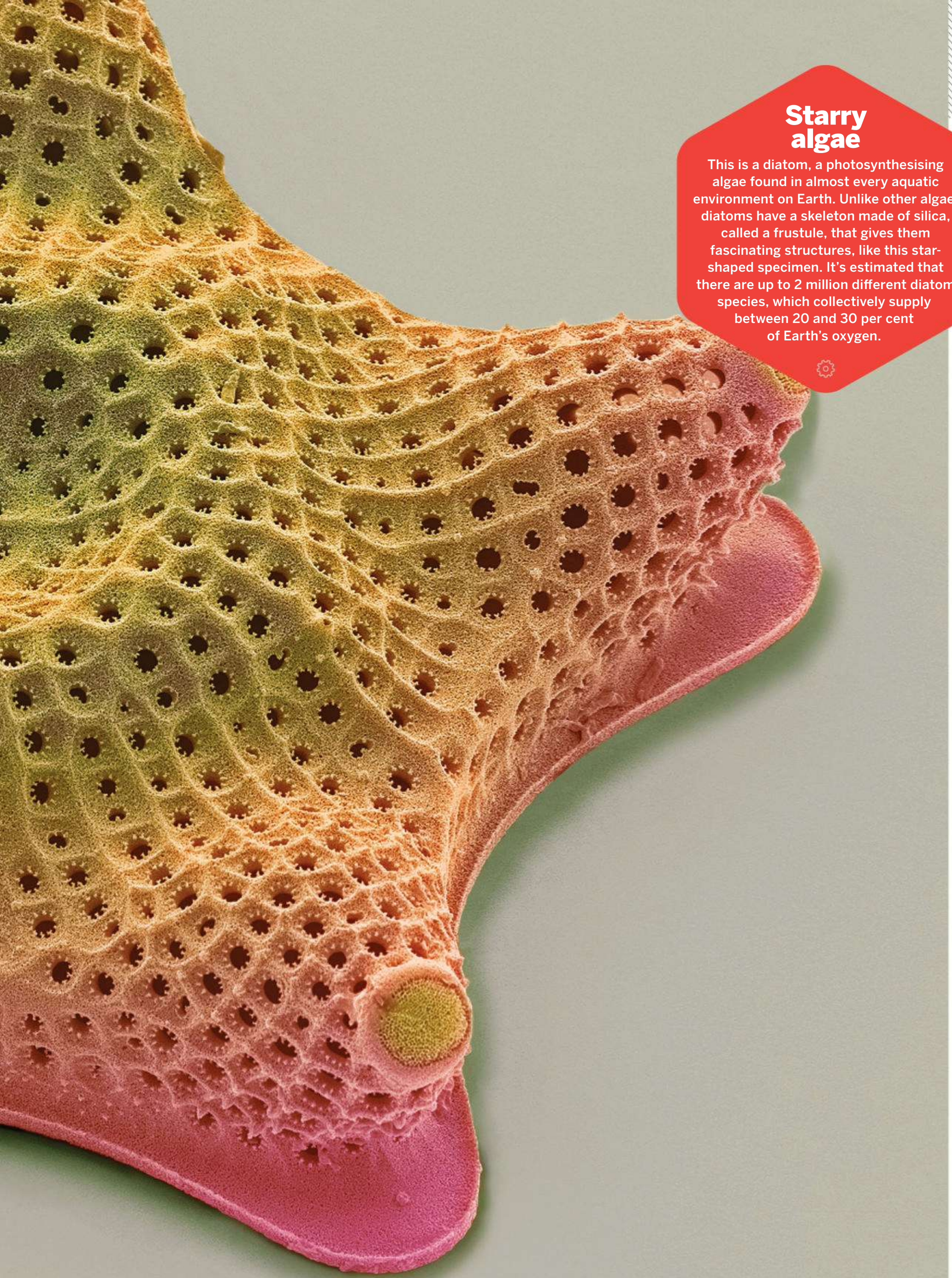

Starry algae

This is a diatom, a photosynthesising algae found in almost every aquatic environment on Earth. Unlike other algae, diatoms have a skeleton made of silica, called a frustule, that gives them fascinating structures, like this star-shaped specimen. It's estimated that there are up to 2 million different diatom species, which collectively supply between 20 and 30 per cent of Earth's oxygen.

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Aurora over Norway

A spectacular view of aurora borealis cascading over Lofoten, a Norwegian archipelago of seven main islands. Thanks to high-speed electrically charged particles crashing into Earth's atmosphere from the Sun, atmospheric oxygen and nitrogen become excited and emit light in the form of an aurora. These bright green and blue ribbons of light are best seen in Norway during dark winter nights.

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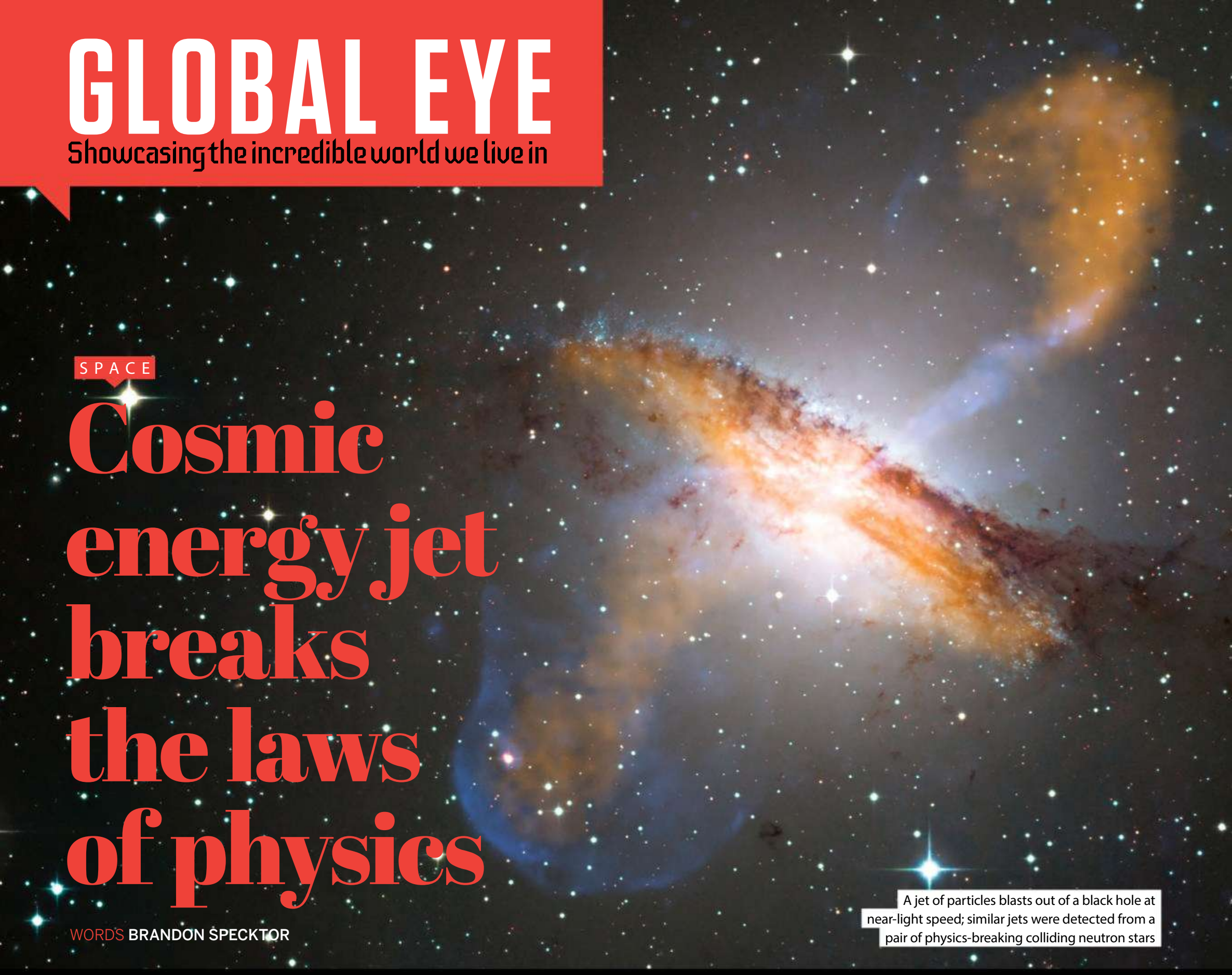
SPACE

Cosmic energy jet breaks the laws of physics

WORD'S BRANDON SPECKTOR



A jet of particles blasts out of a black hole at near-light speed; similar jets were detected from a pair of physics-breaking colliding neutron stars

Astronomers have detected a gargantuan blast of energy from space that appears to be doing the impossible: travelling seven times faster than the speed of light. But this is an optical illusion – a rare and mind-boggling phenomenon called superluminal motion that occurs when particles come very close to moving at the speed of light. In this case, scientists detected a jet of energy blasting out of a stellar collision site at a staggering 99.97 per cent the speed of light, about 670 million miles per hour.

The jet in question is the result of a cosmic cataclysm that first made waves in the scientific community in 2017. That year, scientists detected a violent collision between two neutron stars, ultradense collapsed star cores that pack a Sun's worth of mass into a ball no wider than a city, located roughly 140 million light years from Earth. The collision was so powerful it created ripples in the fabric of space-time; such disturbances are known as gravitational waves.

Einstein predicted the existence of these ripples in 1916, and it took scientists 100 years to find the evidence to prove it after a collision of two black holes was detected in 2016. The gravitational waves released by the colliding neutron stars in 2017, a signal named GW170817, were the first to be detected from a source other than black holes, proving that more than one type of cosmic catastrophe is capable of creating them.

Gravitational waves are invisible to the naked eye, but can be detected with instruments such as the Large Interferometer Gravitational Wave Observatory (LIGO) in Pasadena, California. After LIGO detected the first blast of waves from the colliding stars in 2017, astronomers around the world trained their telescopes on the merger to learn whatever they could about it. Before long, astronomers saw visible evidence of a high-speed jet of particles blazing out of the collision site and lighting up globs of matter that had been ejected by the stars. Astronomers analysed the jet with NASA's Hubble Space Telescope, the European Space Agency's Gaia space observatory and several additional radio telescopes on Earth. With these observations, the team calculated both the actual speed of the jet and the perceived physics-defying speed.

The beyond-light-speed illusion arises from the difference in speed between the particles in the jet and the light particles, or photons, that they emit. Because the jet's particles move nearly as fast as the light they emit, it can appear as though particles in the early part of the jet are arriving at Earth at nearly the same time as photons in the later stages of the jet, making it appear as though the jet is actually moving faster than the speed of light. Astronomers have observed this illusion at play in several other cosmic objects before, including in a near-light-speed jet blasting out of the Messier 87 galaxy in the Virgo constellation. So far, all instances of superluminal motion can be explained with maths in a way that doesn't shatter the known laws of physics.

Most of the gold coins depict the likeness of Byzantine Emperor Heraclius

HISTORY

BURIED TREASURE OF 44 BYZANTINE GOLD COINS DISCOVERED

WORDS **JENNIFER NALEWICKI**

Excavators in Israel have discovered a trove of 44 Byzantine gold coins and other valuables. Coins from the hoard were minted by the Byzantine Empire during the reign of Emperor Phocas and Emperor Heraclius. All of the pieces of money were gold solidus coins, which were common currency during the Byzantine era. Experts from the Israel Antiquities Authority (IAA) dated the latest coins in the cache to the time of the Muslim conquest of Byzantine Palestine, which occurred in 635 BCE.

"Most of the coins are of the Byzantine Emperor Heraclius," said Gabriela Bijovsky, a numismatic expert with the IAA. "And what is particularly interesting is that in his early years as emperor, only his portrait was depicted on the coin, whereas after a short time, the images of his sons also appear. You can actually follow his sons growing up from childhood until their image appears the same size as their father, who is depicted with a long beard."

Researchers discovered the coins at Hermon Stream Nature Reserve in northern Israel, which was once the site of the ancient city of Banias, also known as Paneas or Panias. The coin stash was found lodged into the base of a stone wall, and experts think it was left there by someone who was fleeing during the Muslim conquest.

SPACE

Massive Martian meteor impact is the largest ever recorded

WORDS **DONAVYN COFFEY**

On 24 December 2021, a magnitude 4.0 marsquake rocked the Red Planet, triggering sensors on NASA's Insight. Now scientists know exactly what shook things up. Before and after images captured by NASA's Mars Reconnaissance Orbiter confirmed it was a meteor impact – the largest on record in the entire Solar System. The impact crater, which measures 150 metres across and 21 metres deep and is located near the Martian equator, now offers scientists a rare peek at subsurface Mars. Moreover, boulder-sized chunks of ice that were dislodged and exposed by the blow represent the lowest altitude ice ever found on the planet.

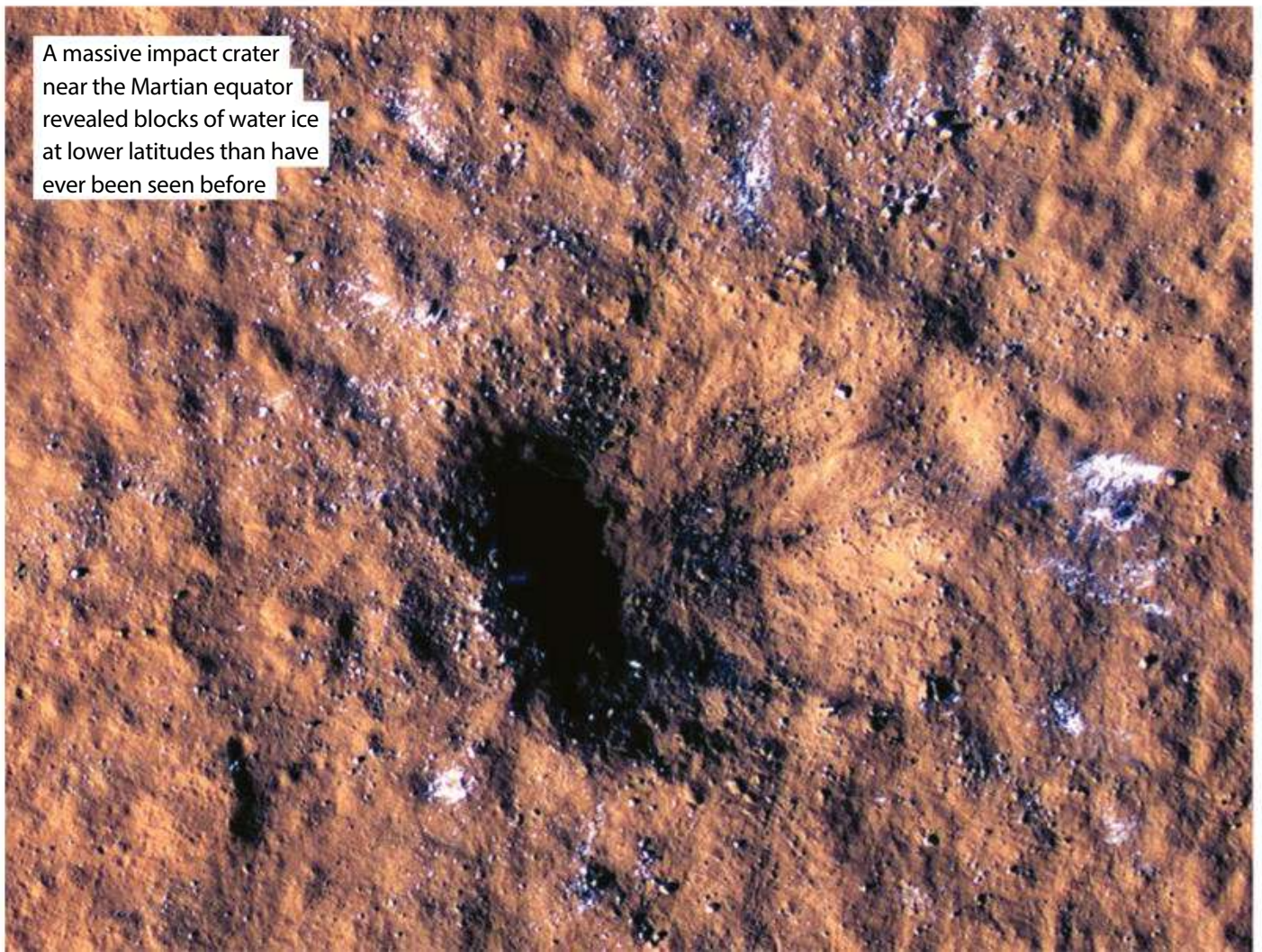
While larger craters exist on the Red Planet, they were formed long before NASA started scouring Mars 16 years ago, so there are no images or seismic data to explain their origin. This quake and crater represent the largest impact ever recorded. "The image of the impact was unlike any I had seen before, with the massive crater, the exposed ice and the dramatic blast zone preserved in the dust," said Liliya Posiolova, who leads the Orbital Science and Operations Group at Malin Space Science Systems (MSSS) in San Diego.

MSSS scientists first visualised the crater on 11 February 2022 using two cameras mounted on the Mars Reconnaissance Orbiter. One of these cameras takes daily photos of the entire planet, so the scientists were able to look back through the daily images to find the meteor's blast zone. Once they found it, they tied the impact to a 24-hour window and confirmed that the crater formed during the 2021 marsquake.

The meteor was so small – no more than 12 metres long – that it would have entirely burned up in Earth's atmosphere. But Mars' thinner atmosphere, only one per cent as dense as Earth's, was less of a deterrent. Observations of the crater at ground level also revealed new information about Mars' geological make-up. "Impact events are extremely helpful in seismology," said Andrea Rajšić, a doctoral candidate at Curtin University in Australia. "This is a fantastic way to peek into the interior structure of the Red Planet."

Did you know?
InSight launched to Mars on 5 May 2018

The subsurface ice that was exposed in the crater and among the ejected debris is closer to the Martian equator than any previously spotted ice specimen on the planet. It could be critical to future missions to Mars, as it hints at a more widespread repository of subsurface ice than was once suspected. Astronauts who will one day visit the Martian surface will need water for drinking, agriculture and rocket propellant. Now NASA is aware that the ice reservoir extends to one of the warmest spots on the planet, hopefully making the work of future astronauts a little easier.



A massive impact crater near the Martian equator revealed blocks of water ice at lower latitudes than have ever been seen before

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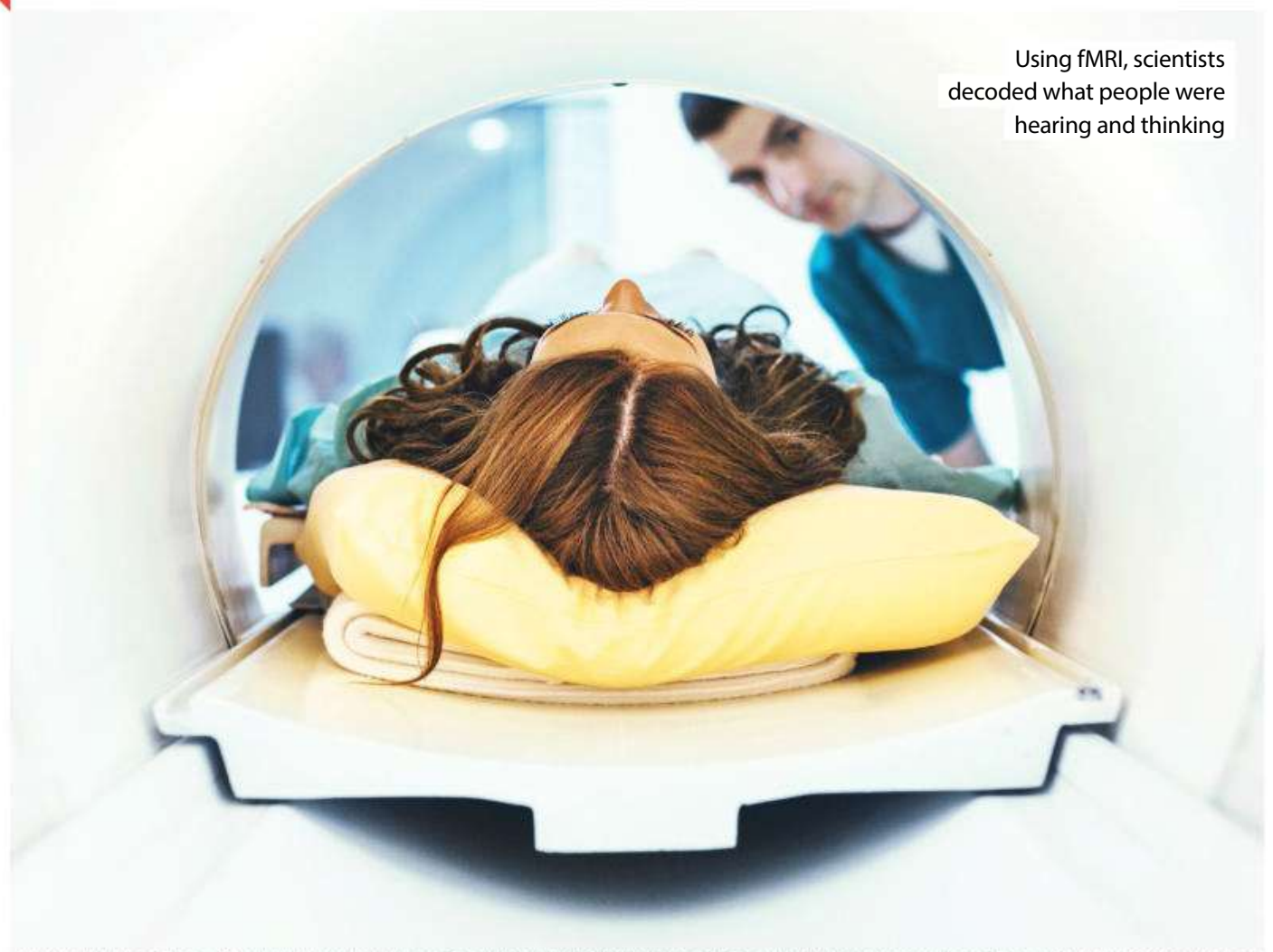


Using fMRI, scientists decoded what people were hearing and thinking

HEALTH

Scientists design an algorithm that 'reads' people's thoughts

WORDS NICOLETTA LANESE

Scientists can now 'decode' people's thoughts without even touching their heads. Past mind-reading techniques relied on implanting electrodes deep in peoples' brains. The new method instead relies on a noninvasive brain scanning technique called functional magnetic resonance imaging (fMRI). fMRI tracks the flow of oxygenated blood through the brain, and because active brain cells need more energy and oxygen, this information provides an indirect measure of brain activity. By its nature, this scanning method cannot capture real-time brain activity, since the electrical signals released by brain cells move much more quickly than blood moves through the brain. But, remarkably, the study authors found that they could still use this imperfect proxy measure to decode the semantic meaning of people's thoughts, although they couldn't produce word-for-word translations. "If you had asked any cognitive neuroscientist in the world 20 years ago if this was doable, they would have laughed you out of the room," senior study author Alexander Huth, a neuroscientist at the University of Texas at Austin, said.

For the new study, which has not yet been peer-reviewed, the team scanned the brains of one woman and two men in their 20s and 30s. Each participant listened to 16 total hours of different podcasts and radio shows over several sessions in the scanner. The team then fed these scans to a computer algorithm that they called a 'decoder', which compared patterns in the audio to patterns in the recorded brain activity. The algorithm could then take an fMRI recording and generate a story based on its content, and that story would match the original plot of the podcast or radio show 'pretty well'. In other words, the decoder could infer what story each participant had heard based on their brain activity. That said, the algorithm did make some mistakes, like switching up characters' pronouns and the use of the first and third person. It "knows what's happening pretty accurately, but not who is doing the things," Huth said.

In additional tests, the algorithm could fairly accurately explain the plot of a silent movie that the participants watched in the scanner. It could even retell a story that the participants imagined telling in their heads. In the long term, the research team aims to develop this technology so that it can be used in brain-computer interfaces designed for people who cannot speak or type.

Did you know?
fMRI techniques were invented in 1990

SPACE

COLLAPSED OBSERVATORY OFFERS ASTEROID WARNING FROM BEYOND THE GRAVE

WORDS ANDREW JONES

Scientists have published a huge study on near-Earth asteroids using data from the collapsed Arecibo Observatory in Puerto Rico. The study contains information on 191 asteroids, using observations collected from the now-defunct Arecibo between December 2017 and December 2019. The data can be used for clues about the spin periods and sizes of many of these asteroids. Observations from Arecibo have contributed to planetary defence efforts, including the recent Double Asteroid Redirection Test (DART), and characteristics of several potentially hazardous asteroids are included in the new paper, which details numerous interesting findings, including two asteroids with abnormally high radar albedos, or reflectivity, suggesting they could be metal-rich. Another highly reflective asteroid, the rare equal-mass binary 2017 YE5, was suggested to have ice below its surface instead of metal richness due to its low bulk density. Overall the data is valuable in a number of ways, including holding potential clues to the evolution of the Solar System and containing valuable information for future endeavours such as asteroid mining.

This aerial view shows a hole in the dish panels of the Arecibo Observatory in Puerto Rico

Fungal DNA was found in different types of tumours

HEALTH

Fungi grow inside cancerous tumours

WORDS NICOLETTA LANESE

Scientists discovered traces of fungi lurking in the tumours of people with different types of cancer, including breast, colon, pancreatic and lung cancers. However, it's still not clear that these fungi play any role in the development or progression of cancer. Two new studies uncovered DNA from fungal cells hiding out in tumours throughout the body. In one study, researchers dusted for the genetic fingerprints of fungi in 35 different cancer types by examining more than 17,000 tissue, blood and plasma samples from cancer patients. Not every single tumour tissue sample tested positive for fungi, but overall the team did find fungi in all 35 cancer types assessed. "Some tumours had no fungi at all, and some had a huge amount of fungi," Ravid Straussman, a cancer biologist at the Weizmann Institute of Science in Rehovot, Israel, said; often when tumours contained fungi, they did so in 'low abundances'.

Based on the amount of fungal DNA his team uncovered, Straussman estimated that some tumours contain one fungal cell for every 1,000 to 10,000 cancer cells. If you consider that a small tumour can be laden with a billion or so cancer cells, you can imagine that fungi may "have a big effect on cancer biology," Straussman said. The research team found that each cancer type tended to be associated with its own unique collection of fungal species; these included typically harmless fungi known to live in humans and some that can cause diseases, like yeast infections. In turn, these fungal species often coexisted with particular bacteria within the tumour. For now it's unknown if and how these microbes interact in the tumour and if their interactions help fuel the cancers' spread.

The second study uncovered similar results to the first, but focused specifically on gastrointestinal, lung and breast tumours. The researchers found that each of those three cancer types tended to host the fungal genuses *Candida*, *Blastomyces* and *Malassezia* respectively. Both research groups found hints that the growth of certain fungi may be linked to worse cancer outcomes. For example, Straussman's group found that breast cancer patients with the fungus *Malassezia globosa* in their tumours showed worse survival rates than patients whose tumours lacked the fungus. The second group found that patients with a relatively high abundance of *Candida* in their gastrointestinal tumours showed increased gene activity linked to rampant inflammation, cancer spread and poor survival rates. Despite these early hints, neither study can definitively say if fungi actually drive these poor outcomes or if aggressive cancers just create an environment where these fungi can easily grow. The studies also don't address if fungi can contribute to cancer development, pushing healthy cells to turn cancerous.

Both studies come with similar limitations. For example, both pulled tissue and blood samples from existing databases, and it's possible that some samples may have been contaminated with fungi during the collection process. Both research groups attempted to weed out such contaminants, but even with these precautions they said that it would be best if the results could be replicated with samples taken in a sterile environment. Straussman said that these initial studies serve as a springboard for future research into mycobiota, meaning the communities of microbes associated with cancers.

© Getty

Woolly mammoths have been extinct for thousands of years, but now a biotech firm wants to bring them back

ANIMALS

THE CIA WANTS TO BRING BACK WOOLLY MAMMOTHS

WORDS **BRANDON SPECKTOR**

The CIA is funding research into resurrecting extinct animals, including the woolly mammoth and tiger-like thylacine. Via a venture capital investment firm called In-Q-Tel, which the CIA funds, the American intelligence agency has pledged money to the Texas-based tech company Colossal Biosciences. The company's goal is to "see the woolly mammoth thunder upon the tundra once again" through the use of genetic engineering – that is, using technology to edit an organism's DNA.

De-extinction may sound like science fiction, and to an extent it is. There's no way to bring back the woolly mammoth as it was ten thousand years ago. However, by using DNA-editing tools, scientists can insert cold-resistant characteristics into the DNA sequences of modern elephants, making them genetically similar to woolly mammoths. The resulting creature wouldn't be a mammoth, per se. It would be a proxy animal that's more like an elephant with mammoth-like characteristics. The foundation of this process is a gene-editing method called CRISPR – genetic 'scissors' that scientists can use to cut, paste and replace specific gene sequences into an organism's DNA. Investing in this project will help the US government "set the ethical, as well as the technological standards" for genetic engineering technology.

ANIMALS

Emperor penguins join the threatened species list

WORDS **NICOLETTA LANESE**

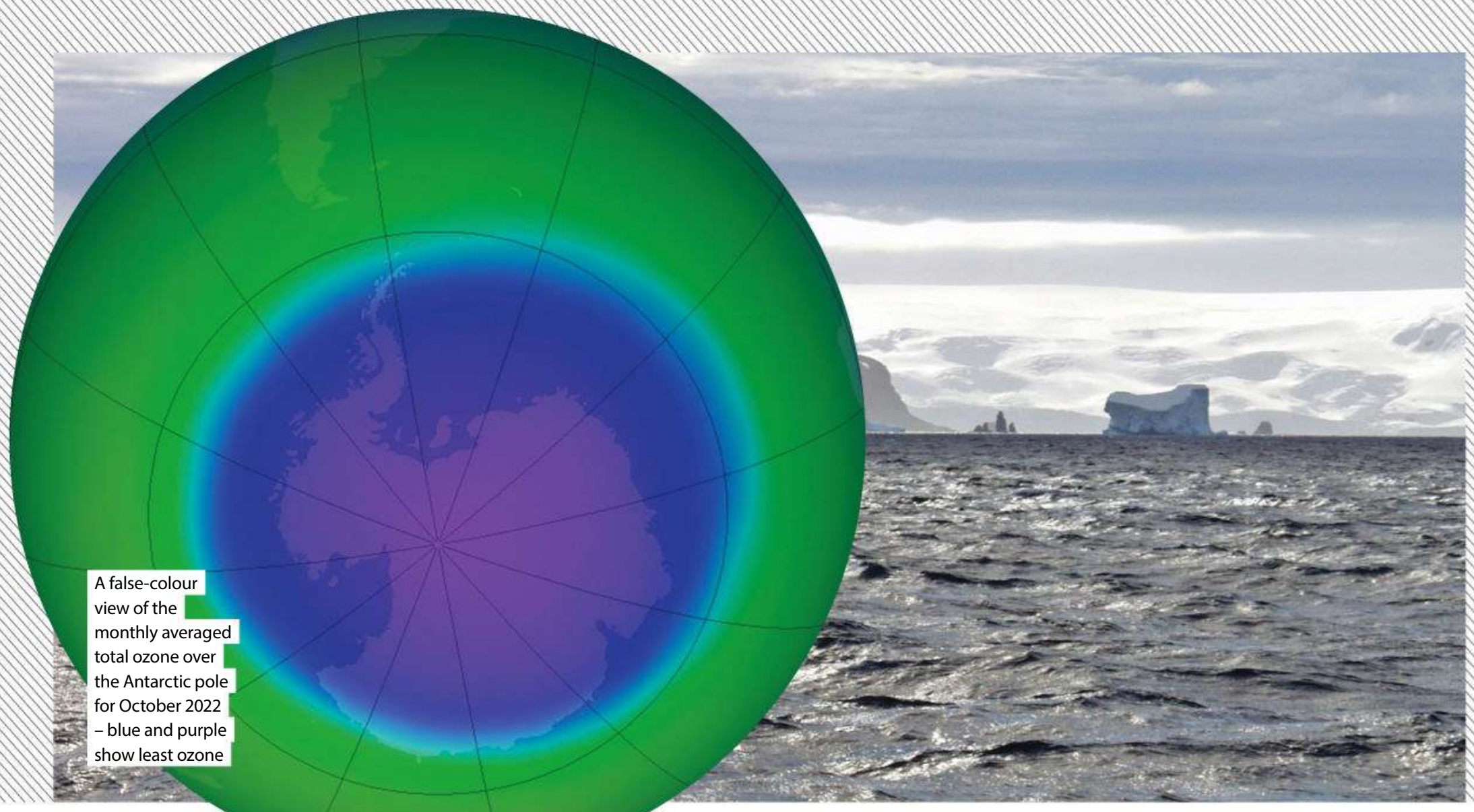
Climate change has pushed emperor penguins, the largest species of penguin, onto the threatened species list, which means the iconic Antarctic birds are likely to become endangered in future. Research published last year highlighted the imminent threats to the survival of emperor penguins (*Aptenodytes forsteri*). It found that up to 70 per cent of emperor penguin colonies in Antarctica could become extinct by 2050 if current rates of sea ice loss continue. In the worst case, 98 per cent of colonies could disappear by 2100, leaving the species unable to rebound. These harrowing findings prompted the US Fish and Wildlife Service (USFWS) to propose protecting emperor penguins under the Endangered Species Act (ESA).

On 25 October USFWS officially declared the emperor penguin to be a threatened species, extending their protections under the ESA. "This listing reflects the growing extinction crisis and highlights the importance of the ESA and efforts to conserve species before population declines become irreversible," said USFWS director Martha Williams. "Climate change is having a profound impact on species around the world and addressing it is a priority. The listing of the emperor penguin serves as an alarm bell, but also a call to action."

There are currently about 61 breeding colonies of emperor penguins living along the coastline of Antarctica, which include roughly 270,000 to 280,000 breeding pairs. These populations seem stable, but due to anticipated sea ice loss, the flightless bird's numbers are expected to decline "in a significant portion of its range." Models suggest that if humans manage to curb carbon emissions dramatically, global emperor penguin populations could dwindle by about 26 per cent by 2050. But in a high-carbon-emission scenario, the populations could fall by more than 50 per cent in the same time frame. Notably, these losses would not be dispersed evenly throughout the global *A. forsteri* population.

"The Ross and Weddell seas are strongholds for the species, and populations in these areas will most likely remain stable," USFWS officials stated. "However, emperor penguin colonies within the Indian Ocean, Western Pacific Ocean, Bellingshausen Sea and Amundsen Sea sectors are projected to decline by over 90 per cent due to melting sea ice." Issuing protections for emperor penguins under the ESA could potentially help bolster the species against population decline. Specifically, designating the species as threatened "promotes international cooperation on conservation strategies, increases funding for conservation programs, spurs research and provides concrete tools for threat reductions," according to the Woods Hole Oceanographic Institution.

Emperor penguins may soon become endangered if swift measures aren't taken to protect them



A false-colour view of the monthly averaged total ozone over the Antarctic pole for October 2022 – blue and purple show least ozone

PLANET EARTH

Ozone layer hole has grown for a third year in a row

WORDS **JOANNA WENDEL**

The ozone hole that forms yearly over Antarctica has grown for the third year in a row. At nearly 10 million square miles, the ozone hole is the largest it's been since 2015. But despite that growth, scientists say that the hole's size is still on a downward trend overall. "All the data says that the ozone is on the mend," Paul Newman, NASA Goddard Space Flight Center's chief Earth scientist, said.

Ozone is composed of three oxygen atoms and makes up very little of our atmosphere, but it has a huge impact on our planet. The blanket-like layer stretching over the globe absorbs the most harmful ultraviolet (UV) radiation from the Sun, shielding Earth's life. Ozone forms in the stratosphere, around 9 to 18 miles above Earth's surface. It forms when UV radiation splits regular oxygen molecules, which are made of two oxygen atoms (O_2). The two free-floating oxygen atoms then each bond with an oxygen molecule, forming a molecule made of three oxygen atoms.

Scientists discovered the thinning ozone layer over Antarctica in the early 1980s. Although ozone is created and destroyed naturally in the stratosphere, human-driven pollution destroys ozone faster than it can form. In particular, industries that use chlorine or bromine, like refrigeration and air conditioning, destroy ozone at alarmingly high rates. In the stratosphere, chlorine molecules react with ozone to create one chlorine monoxide molecule – composed of a chlorine atom and an oxygen atom – and one O_2 molecule. Then the chlorine monoxide molecule breaks down, freeing that chlorine atom to react with more ozone. One atom of chlorine can destroy 100,000 ozone molecules before that chlorine molecule is removed from the atmosphere. Substances like chlorofluorocarbons, used in refrigeration and air conditioning, stay in the atmosphere for a long time, some for longer than six months, meaning the chlorine and other chemicals from these substances can wreak havoc on the ozone layer.

The ozone hole was first observed in the early 1980s and reached its largest extent in 2006. This year's ozone hole, which peaked on 5 October, was the biggest recorded since 2015. But scientists aren't too concerned. "The overall trend is improvement. It's a little worse this year because it was a little colder this year," said Newman.

A cold stratosphere is exactly what chemicals like chlorine need to break down ozone. During Antarctica's winter, the stratosphere gets cold enough for clouds to form. The ice crystals that make up those clouds provide a surface on which chlorine, for instance, can react with ozone. As spring approaches in September, the Sun's UV rays jumpstart these reactions. Once summer is in full swing, the stratosphere warms up enough to evaporate the clouds, removing the surface on which ozone-destroying chemical reactions take place. Global agreements like the 1987 Montreal Protocol, which regulates the production and consumption of ozone-depleting substances, have helped to repair the ozone hole. And despite the ozone hole's increasing size this year, scientists generally agree that the hole is shrinking.

Did you know?

Ground-level ozone is harmful to life on Earth

© Alamy / Getty / NASA

Iceberg A-68a, one of the largest ever recorded, floating near South Georgia Island

PLANET EARTH

Powerful ocean currents snap Antarctic iceberg in two

WORDS JENNIFER NALEWICKI

A swift change in ocean currents in the Southern Ocean likely snapped one of the largest icebergs in half like a twig. The gigantic ice mass, called A-68a, was known as a tabular iceberg due to its rectangular shape. At its largest it was roughly the size of Delaware, covering approximately 2,300 square miles, and in 2017 it famously calved off another iceberg, A-68, dumping 1 trillion tonnes of meltwater into the ocean over the three years it was seabound. But scientists didn't know what caused A-68a to break apart.

In a recent study, researchers used satellite imagery and datasets to travel back in time to December 2020, when the finger-shaped iceberg experienced two breakdown events. After passing by South Georgia Island, A-68a began fracturing, with a large chunk breaking off as a direct result of the iceberg's keel dragging on the seafloor. However, the second event befuddled experts since the iceberg was floating in the deep open ocean. "Usually, icebergs break because they run into the seafloor, causing parts of it to break off," said Alex Huth, a postdoctoral research associate in the program in Atmospheric and Oceanic Sciences (AOS) at Princeton University. "But in this case, after looking at the ocean current data, the finger-like portion of the iceberg seemed to be overlapping one part of the current that was stronger than another part, so it seems reasonable to suspect that it caused enough tension along the iceberg's body to snap it in half like a toothpick."

The researchers theorised that the second breakdown event was triggered by ocean-current shear and that a change in currents led to part of the iceberg being lopped off – something that hadn't been reported before. To test their theory, they looked at how outside forces such as ocean currents and wind could impact the iceberg. Creating a simulation of A-86a using a model called Kinematic Iceberg Dynamics (iKID), the team found that "when [an iceberg] becomes positioned into a current that's very strong versus another current that's very weak, the bonds between [conglomerate] particles will snap, and we were able to model the actual fracture of the berg."

The iceberg's finger-like shape may have also contributed to the fracture, Huth said, "since it made the berg long enough to overlap the two currents". Researchers also examined whether or not preexisting cracks encouraged the breakup. However, Huth said that remains inconclusive since "the main part of the fracture doesn't seem to follow along a preexisting crack".

By studying the demise of A-68a, Huth and his team believe they can get a better sense of the role icebergs play on Earth's system and how they interact with outside forces. "Icebergs represent roughly 50 per cent of the ice mass loss of Antarctica, which happens when they calve off ice sheets," Huth said. "As they drift away, they deposit meltwater far away from the sheets. This can influence ocean circulation by stratifying the water column and can essentially fertilise the ocean with iron since they're a source of sediment from Antarctica, which can lead to an increase in phytoplankton."

NASA has launched a nine-month study into UFOs, also called unidentified aerial phenomena

STRANGE NEWS

UFOs are finally getting a big NASA study

WORDS **BRANDON SPECKTOR**

On 24 October NASA officially launched an independent study into UFOs – or unidentified aerial phenomena (UAPs). A team of 16 leading experts, including astrophysicists, aerospace industry executives and former astronauts, will dig into as much data as possible about reported UAP sightings. It will lay the groundwork for a future study on the nature of UAPs at NASA and across government agencies. "Exploring the unknown in space and the atmosphere is at the heart of who we are at NASA," said Thomas Zurbuchen, associate administrator of the Science Mission Directorate at NASA's Washington DC headquarters. "Understanding the data we have surrounding unidentified aerial phenomena is critical to helping us draw scientific conclusions about what is happening in our skies."

During the nine-month investigation, the study team will look at unclassified data gathered by civilians, government agencies and private companies related to any observations in the sky that cannot be identified as aircraft or natural phenomena. The team's three-pronged approach will include identifying available UAP data, figuring out ways to gather more data in the future and developing methods for studying that data in ways that advance NASA's scientific understanding of UAPs. The agency will publicly release a report on its findings in mid-2023. There's no evidence that UAPs are related to aliens, NASA noted. However, the space agency has numerous research programs devoted to uncovering signs of extraterrestrial life in the Solar System, including potential microbial life on Mars and far, far beyond.

According to a 2021 report from the US Office of the Director of National Intelligence, the most likely explanations for UAPs are airborne clutter such as birds and balloons, atmospheric phenomena such as ice crystals, classified government projects or "technologies deployed by China, Russia, another nation or a non-governmental entity".

Outside of NASA, the US government's renewed interest in UAP investigations dates to 2017, when several videos taken by US Navy aircraft leaked to the media. The now-infamous videos showed unidentified aircraft moving in seemingly impossible ways, with no explanation. The government subsequently declassified the footage, and in September of this year revealed that there is more military footage of UAP encounters. However, the Department of Defense (DoD) will not be releasing the footage due to national security concerns. In July, Congress approved funding for the DoD to open a new office focused exclusively on managing reports of UFO sightings by the US military.

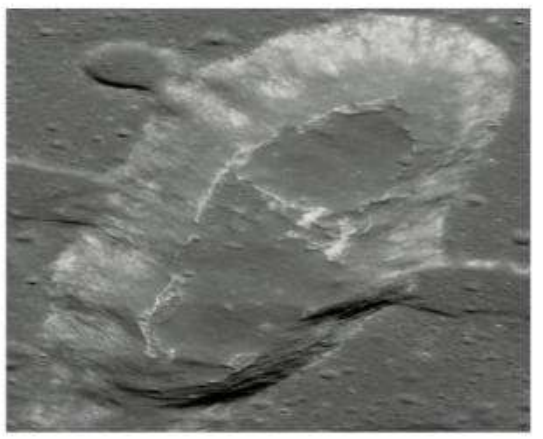
SPACE

CHINESE MOON MISSION UPENDS THEORIES OF LUNAR VOLCANISM

WORDS **ANDREW JONES**

An analysis of lunar samples returned by China's Chang'e 5 has produced a new possible answer for volcanism late in the Moon's history. Samples returned by the Apollo and Luna missions are all older than 3 billion years, but samples returned by Chang'e 5 in late 2020 confirmed that rocks in the area were only 2 billion years old. Scientists speculated that either a relatively high water content or the presence of radioactive heat-producing elements in the lunar interior might have driven volcanism in some areas, but new data appears to have ruled out these hypotheses.

Researchers led by Chen Yi from the Institute of Geology and Geophysics of the Chinese Academy of Sciences found that a lower melting point for portions of the lunar mantle could be due to the presence of fusible easily melted components, leading to young lunar volcanism. Researchers conducted a series of simulations to compare 27 samples of Chang'e 5 basalt clasts with Apollo basalts. They found that the young magma collected by Chang'e 5 had higher calcium oxide and titanium dioxide contents than older Apollo magmas. These late-stage lunar magma ocean cumulates are more easily melted than early cumulates.



Basaltic eruptions make mounded patches in mare pits like this one on the lunar surface

© Wiki: Cpl Phil Dye RA / Getty / NASA/GSFC/Arizona State University

WISH LIST

The latest tech for CHRISTMAS

HOMESTAR PLANETARIUM

WWW.SEGATOYS.SPACE £104 (APPROX. $119.60)

Imagine enjoying a sky full of stars from the comfort of your own home. This dream can become reality with the Homestar Original from Sega Toys. This high-definition planetarium has an ultrabright three-watt LED and rotating movement that can project the night sky onto your ceiling throughout the year. Two interchangeable discs containing the fixed stars of the Northern Hemisphere will enable you to observe the night sky or a map of the constellations, and with the integrated 'shooting star' function you can have a meteor shower at home too. The projection angle and focus are adjustable and a handy timer turns off the planetarium automatically, allowing you to fall asleep while gazing at the stars.

PLAYSHIFU TACTO GAME SETS

WWW.PLAYSHIFU.COM

FROM £44.99 (APPROX. $51.75)

Turn your tablet into an interactive game board with this range of fun game sets. The Tacto game sets feature physical playing pieces and will convert iPads, Amazon Fire and Android tablets into a game board. One of the sets is a chessboard that teaches children the basics of chess through fun story-led games. Players can either compete against each other or take their chances with an AI adversary or move predictor. There are also more than 100 mini-puzzles to complete. Chess is just one of the many different PlayShifu game sets available for the whole family to enjoy, including circuit building, code writing, laser puzzles and classic games such as Ludo and Checkers. PlayShifu's creations would make a fun and innovative gift for your young ones this Christmas.

JUNIORSCOPE

WWW.MICROSCOPE.COM

$130 (APPROX. £113)

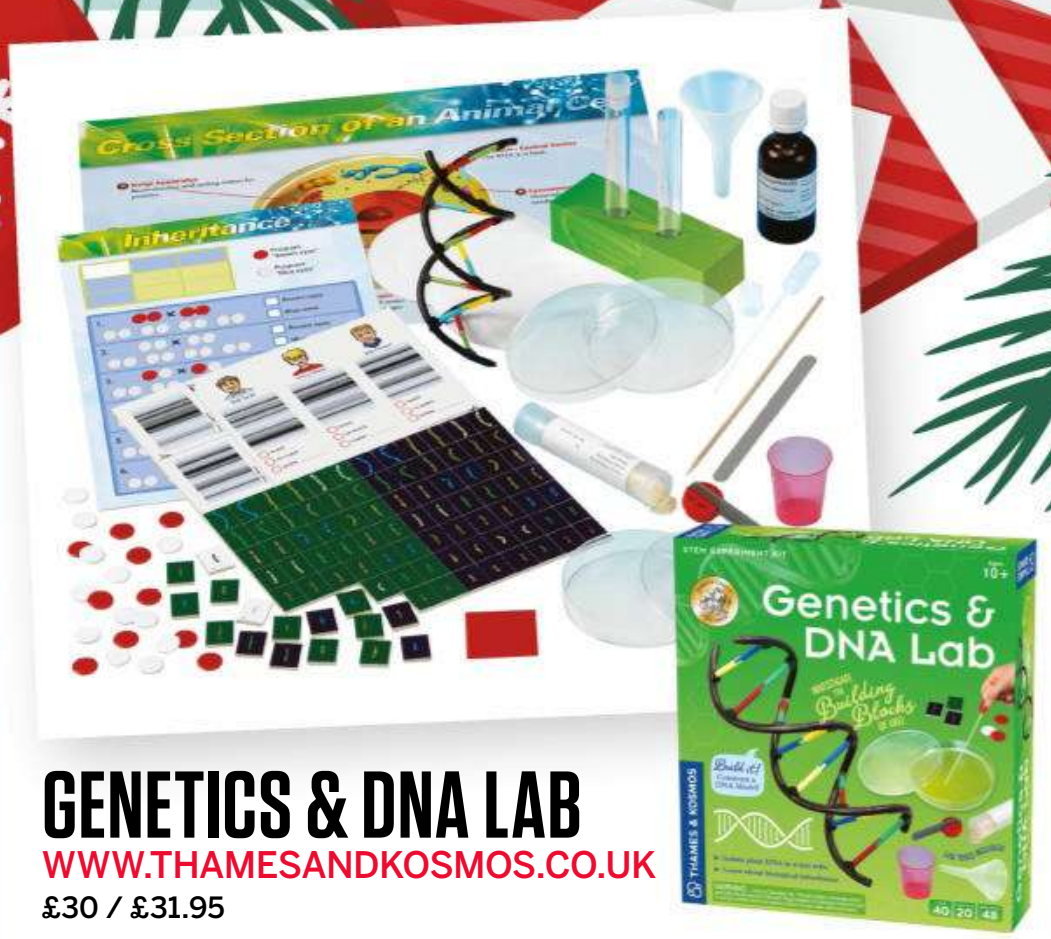
The Omano JuniorScope is a professional-looking monocular microscope that will make a great gift this Christmas. This microscope is most useful for taking a closer look at plants, rocks, insects and skin tissue. It's also more robust than many other children's microscopes, made from sturdy metal and plastic components. From examining candy canes to marvelling at mistletoe plant cells, young students can use this fantastic LED-powered microscope to magnify Christmas in crystal clarity. The JuniorScope comes with batteries pre-installed, so it's ready to use straight after it's been unwrapped. The microscope is bundled with a variety of scientific tools, such as slides, tweezers, a dropper and a petri dish, to aid young science students every step of the way.

AIRFIX PAGANI HUAYRA STARTER SET

WWW.UK.AIRFIX.COM

£14.99 / $19.99

If you're looking for a great Christmas gift for motorheads and model builders, Airfix has a great range of models to choose from, including the Pagani Huayra. Named after the wind god Quechua, this twin-turbo sports car can reach up to 60 miles per hour in just three seconds and hit a top speed of 238 miles per hour. The 1:43 scale model remarkably showcases the sleek aerodynamic design of the vehicle. This would make a great gift for model enthusiasts or for those that want to explore model making. With only 33 parts to construct and all the equipment you need, such as paints, glue and brushes, this model kit is a perfect present for beginner builders.



GENETICS & DNA LAB

WWW.THAMESANDKOSMOS.CO.UK

£30 / £31.95

Create your own genetic laboratory with this in-depth science kit for kids. Using the 48-page manual, budding scientists can explore the world of DNA and complete heaps of experiments. With each investigation children will learn all about dominant and recessive genes, inheritance, mutations and much more. There's also a 3D model of a double-stranded DNA helix to assemble while discovering the many components that make up our genetic information. Along with experiments, there's also a fun crime-solving activity where you compare the DNA of suspects to identify the guilty party. The Genetics & DNA Lab would make an intriguing Christmas gift for any young science-lover aged ten years or older.

ADOPT AN ORCA

WWW.WHALES.ORG/SUPPORT/ADOPT

FROM £4 PER MONTH (APPROX. $4.60 PER MONTH)

Adopt an orca this Christmas and receive your own personalised adoption certificate featuring a stunning picture of your adopted orca, a set of stickers, a colourful badge and a 36-page colouring book designed by Button & Squirt. You also get a quarterly copy of *SPLASH!* magazine, a monthly e-newsletter and you'll receive email birthday and Christmas cards. Whale and Dolphin Conservation is the leading global charity dedicated to the protection of whales, dolphins and porpoises. Operating for over 30 years, WDC campaigns around the world to end whale and dolphin death in nets, captivity and from whaling and the promotion of healthy and sustainable seas. Whales and dolphins are the heart of a healthy ocean, so they need as much protection as they can get.

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ON THE BATTLEFIELD WITH ROBOT DOGS
WHERE DO GIANT ICEBERGS COME FROM?
SMART ASTRONAUT ASSISTANT
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SCIENCE TECH ENVIRONMENT SPACE HISTORY TRANSPORT

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AI SPECIAL

DID YOU KNOW? By 2024, more than 8 billion voice-activated assistants will be in use worldwide

HOW AI WILL CHANGE YOUR FUTURE

Artificial intelligence is no longer the stuff of science fiction. Here are the many ways it's changing our world

WORDS **SCOTT DUTFIELD**

The term 'artificial intelligence', or AI, was first used by American computer scientist John McCarthy in 1955 and relates to the science of making machines 'intelligent'. But AI isn't a recent technology – the concept has been around since the early 1900s as basic programs to solve mathematical equations. British logician Alan Turing famously cracked German military code during World War II, but he also designed one of the first 'intelligent' machines, now known as the Turing machine. The tape-driven device was created to solve simple calculations such as the square root of high numbers, and can even solve a sudoku puzzle.

Since then, AI has become a multibillion pound industry that has infiltrated every sector in some way. Today you would be hard-pressed to look around a room and not find some form of AI-assisted technology. Smart assistants such as Alexa, smartphone facial recognition, spell checking and even your Netflix suggestions all use AI that learns your preferences, physical qualities and online behaviour. AI learns all these things similar to the way the human brain learns.

At the most basic level, information that's fed by your senses to your brain, such as sight, sound and taste, is translated and given meaning. When you hear a meow, your brain recognises the noise and correctly associates it with a cat. The aural information is detected by the ears, an electrical signal is generated and carried through cells called neurons, translated by the brain and attributed meaning.

Did you know?

82 million Amazon Echo devices were sold in 2022

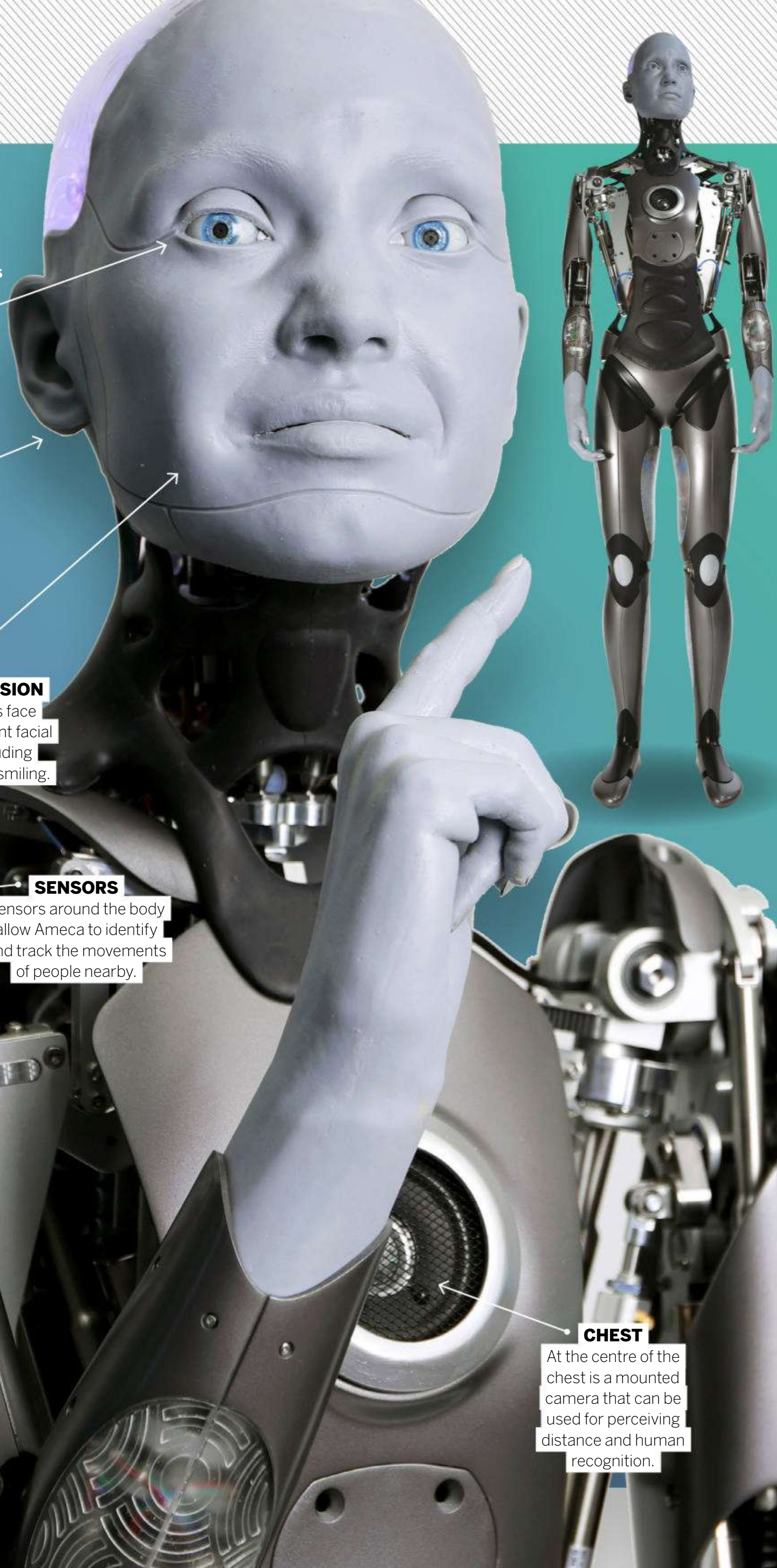
THE THINKING MACHINE

The concept of artificial intelligence might seem like a modern-day technological venture, but the first piece of technology that was comparable to human intelligence was created in 1956 by computer pioneers Herbert A. Simon and Allen Newell. Also known as the 'thinking machine', the Logic Theorist was a computer program to solve mathematical statements laid out in a collection of foundational mathematics books called *Principia Mathematica*, written by Alfred North Whitehead and Bertrand Russell. Of the 52 statements or theorems in the books, the Logic Theorist proved 38 of them and even offered a more in-depth answer to one theorem than that put forward by its creators.

© Engineered Arts

INSIDE AMECA

The technology behind one of the world's most advanced AI humanoids



EYES
Binocular eye-mounted cameras are able to detect and track faces and identify genders, emotions and ages.

EARS
Binaural ear-mounted microphones allow Ameca to hear, carry out voice recognition and offer a response through a speaker.

FACIAL EXPRESSION
Motors in Ameca's face allow it to pull different facial expressions, including anger, surprise and smiling.

SENSORS
Sensors around the body allow Ameca to identify and track the movements of people nearby.

ARMS
Ameca has 51 different articulated movements that allow it to gesture during conversation.

CHEST
At the centre of the chest is a mounted camera that can be used for perceiving distance and human recognition.

DID YOU KNOW? Saudi Arabia granted Sophia, an AI-enabled humanoid, citizenship in 2017

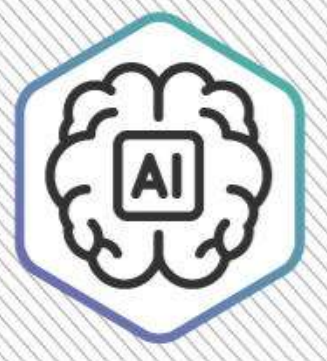
TYPES OF AI

ARTIFICIAL NARROW INTELLIGENCE (ANI)

The ability of an AI to perform and complete a single task. These tasks can include facial recognition, browsing the internet or playing games like chess. While classed as intelligent, these AI systems are limited to their programmed task.

ARTIFICIAL GENERAL INTELLIGENCE (AGI)

The intention of AGI is to perform a task in a comparable way to humans. It would theoretically replicate the human brain and its ability to analyse and respond to multiple stimuli at once. This is still an emerging type of AI and is not yet fully realised.



ARTIFICIAL SUPER INTELLIGENCE (ASI)

At the point at which an AI program supersedes human cognitive ability and can 'think for itself', it will become an artificial super intelligence. An ASI system would theoretically think extraordinarily and achieve things a single human being might not.

AI works in much the same way, but instead of a complex network of biological cells, it uses coded algorithms to make associations with a set of instructions laid out by a programmer, as well as incoming information, to complete a task. The more information an AI program is fed, the more connections it makes and the better it understands and grows, known as 'machine learning'. The more complex and diverse the network of algorithms is, often referred to as a 'neural network', the more it can achieve.

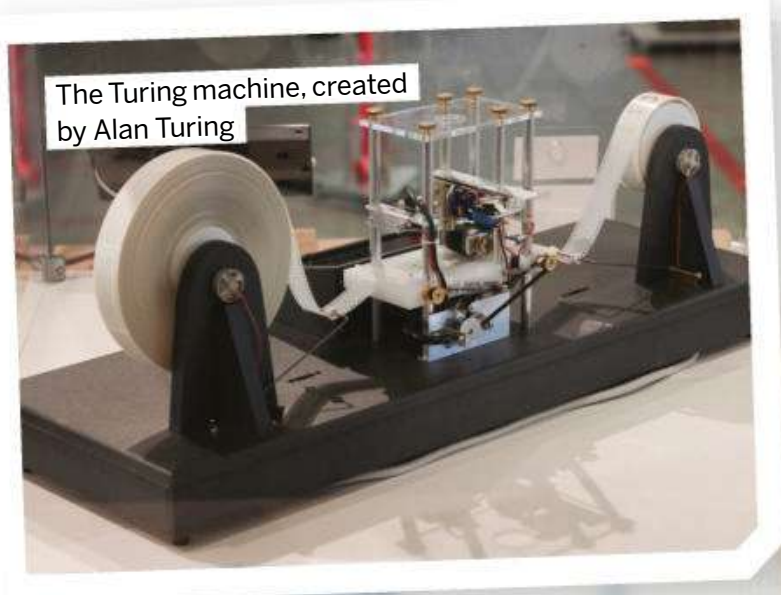
Did you know?

Four out of five companies deem AI a top priority

Currently, AI is divided into different levels of capability. Completing a single task is the most basic level, which can be anything from voice recognition to finding information online, customised advertisements or even predicting the weather. Where AI and the brain differ is in their complexities. While AI technology can be 'smarter' than a human thanks to the wealth of information it has available to it – mainly the internet – it's a long way from emulating the divergent thinking of the human brain. At present, one of the most advanced pieces of general AI technology is called Gato. Created by DeepMind, Gato is an AI model that's been created to solve multiple unrelated problems and perform hundreds of different tasks, such as language processing, playing video games and image identification.

Artificial general intelligence in popular culture is associated with the rise of a robot empire or a beloved AI assistant turned bad. In reality, AI remains a useful software tool both in commercial and business worlds, with only a handful of examples of the technology being integrated into humanoid robots, such as Ameca. Ameca is powered by several pieces of software to give it the ability to interact with people. One of these is TinMan, a telepresence technology that gives Ameca the ability to recognise faces, perceive relative distance and have conversations with people.

Ameca has a modular design, thus its AI functions and abilities can be tailored to the needs of companies that purchase it. So far Ameca has been used for entertainment and social engagements, though there's plenty of opportunity for humanoid interaction. At the moment Ameca is

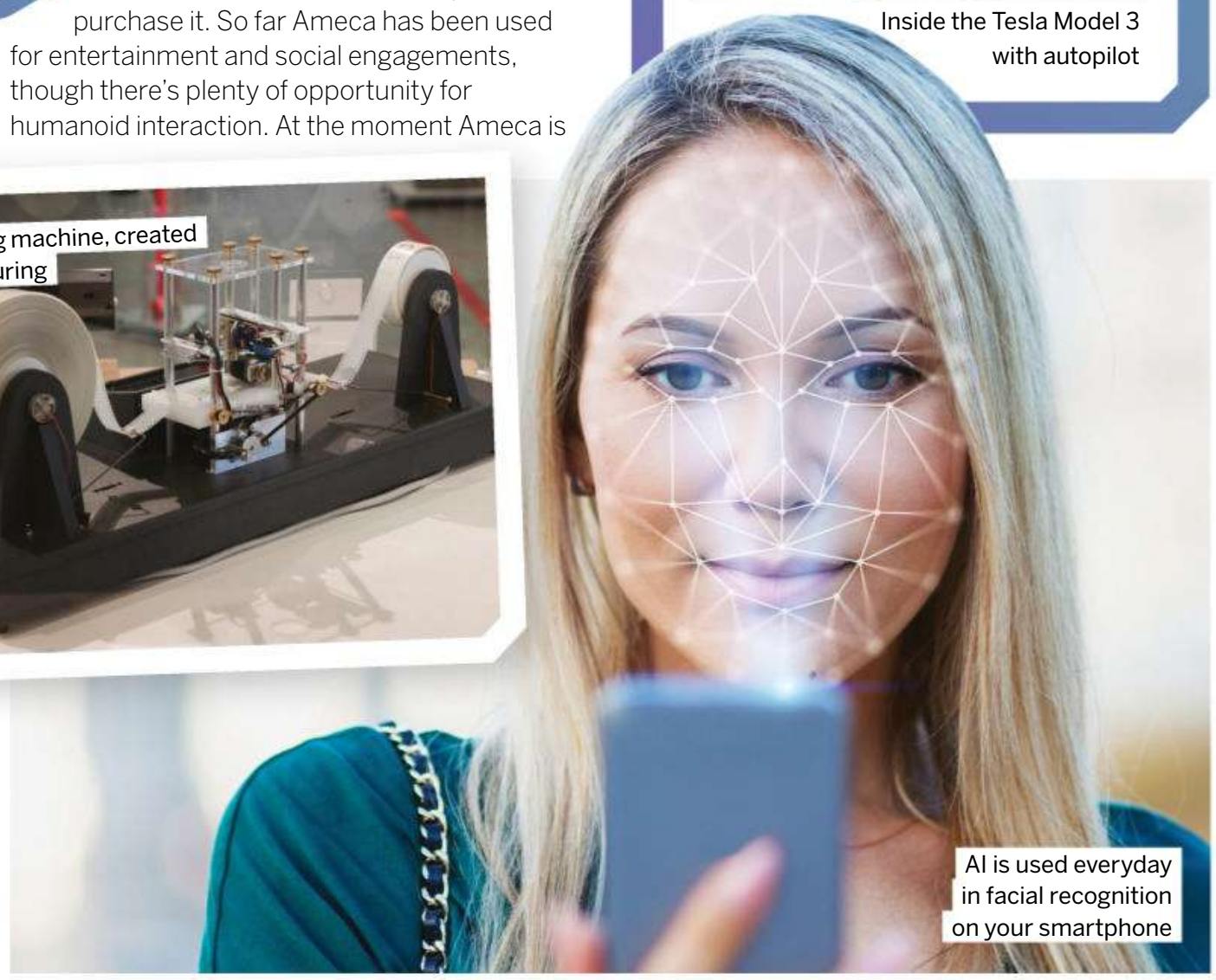


The Turing machine, created by Alan Turing

AI ON THE ROADS

AI is also utilised in autonomous cars and traffic control. In Tesla cars, AI is used to anticipate the movement of the objects around vehicles, such as pedestrians and cyclists. Car manufacturers including Tesla have also created thousands of autonomous self-driving vehicles with AI software, which has been trained by Tesla supercomputers. Tesla's AI software has been developed to comb through raw footage during a drive and detect potential road obstacles, layouts and much more. Building one of Tesla's full AI autopilot neural networks takes 70,000 GPU hours to train.

Inside the Tesla Model 3 with autopilot



AI is used everyday in facial recognition on your smartphone

© Getty / Rocky Acosta / Engineered Arts

Did you know?

MIT has created the first AI horror author, called Shelly

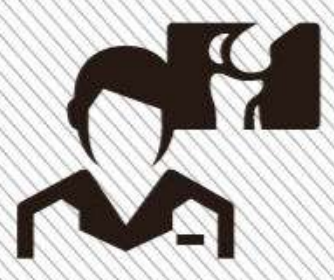
DIAGNOSIS WITHOUT DOCTORS

How AI uses test results to make medical predictions

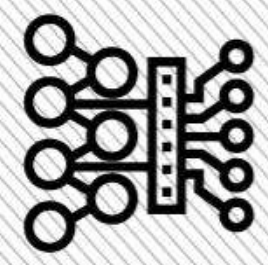
1 SCANS
An AI program will be fed information such as a patent's X-ray or MRI scan.

2 NEURAL NETWORK
A set of algorithms look at the information presented in the scans and compare that to thousands of images and pieces of information.

3 RESULTS
The AI program will make a diagnosis. In lung X-rays, AI may be able to decide if there's evidence of pneumonia or not.



4 CONSULTATION
A human radiologist might then review a scan that the AI has identified as a possible illness, such as pneumonia in the lungs.



5 BETTER OUTCOMES
A collaboration between humans and AI could increase the chance of illness being identified. In a study exploring human-AI hybrid models of diagnosing enlarged hearts, researchers found that together they performed eight per cent better than they would apart.

limited to communication, facial expressions and arm movements. But one of the next stages of its development is to incorporate the ability to use its legs to walk.

Similarly, one of Elon Musk's latest technological ventures is a humanoid robot called Optimus. Although Optimus shares some of the same AI software as Tesla's vehicles, Musk says that existing humanoid robots are "missing a brain" and are unable to navigate the world like humans. Beyond the scope of general intelligence, when a piece of AI surpasses its ability to generally make decisions and interact with its environment, the hope for many AI engineers is that it may one day supersede human intelligence, though scientists are far from creating a piece of AI that can outdo the complex functions of the human brain.

Along with the everyday tasks of checking the weather with a home assistant or sifting through social media, AI has the ability to rapidly advance vital areas in society, including healthcare. The fundamental role of a doctor is to diagnose and treat the myriad of ailments and illnesses of the world. The ability to do so is based on years of education and training to recognise the signs and symptoms of these illnesses. But what if you could teach an AI program to do the same?

Scientists at the National Cancer Institute have put an AI algorithm for diagnosing cancer without human intervention to the test. Using magnetic resonance imaging (MRI) scans, the AI program analysed thousands of images of healthy organs, such as the brain and prostate, along with scans of cancer-afflicted organs. Over time the program has evolved to recognise cancers within the scans and offer doctors a second pair of eyes, acting as a 'virtual expert' to guide training radiologists. Researchers at Imperial College London have also used AI to develop and trial BrainWear, a system that monitors the progress of brain tumours. The impacts of AI diagnosis are paramount, but a world with healthcare run by AI remains fiction for now. Though its breadth of diagnostic ability could potentially exceed the memory storage of the human brain, decisions about treatment remain in the hands of human doctors.

AI's uses also extend beyond hospital walls and onto the battlefield. Currently, armed forces around the world are exploring the possible use of artificial intelligence in two ways. Firstly, for sensory tasks such as identifying a target through a drone or robotic cameras. The second is its role in autonomous movement and obstacle avoidance for robotic members of the armed forces, such as bomb-disposal robots and airstrike drones. Modern-day use of AI in the military remains a tool that works alongside human soldiers to carry out operations and tasks. There are no current examples of completely autonomous AI-controlled robots or drones with lethal capabilities – these still require a human controller.

5 FACTS ABOUT AI IN THE MILITARY

1 INTELLIGENCE
AI can be used to detect potential threats across the land, sea and skies.

2 BOMB DISPOSAL
AI and autonomous robotics in the armed forces are able to enter dangerous areas and defuse threats without risking human lives.

3 DRONES
AI and drone pilots work together to accurately locate targets for surveillance or airstrikes.

4 PERSONNEL
AI is also lending a helping hand in military administrative resources, such as calculating the correct number of medical staff needed.

5 TRAINING
AI and virtual simulations can be used in combat training to offer realistic and reactive scenarios for soldiers to learn from.

AI is changing the way doctors are able to diagnose diseases

DID YOU KNOW? The highest price paid for AI-generated art is $432,000 (£382,000)

AI IN SPACE

How CIMON lends a hand on the ISS

1 CAMERA
An integrated high-resolution camera acts as CIMON's 'eyes' for facial recognition.

5 FACE
Along with a smiling face, CIMON can show experiment instructions and data on its display.

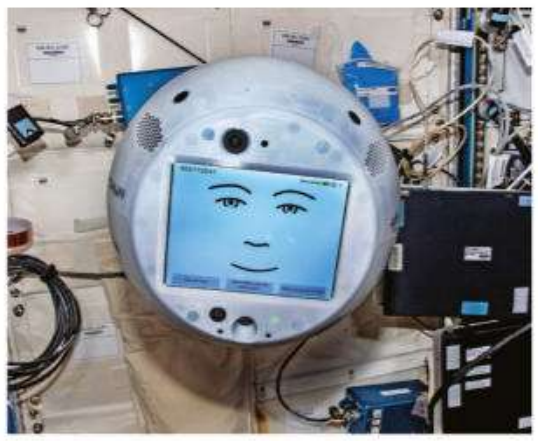
2 SENSORS
To prevent possible collisions on the ISS, CIMON is fitted with an ultrasonic sensor to gauge distances.

4 MICROPHONE
CIMON has eight microphones for voice and directional recognition and a single loudspeaker in its mouth.

3 FANS
12 internal fans allow CIMON to move freely around the ISS.

SPACE EXPLORATION

Meet CIMON, the Crew Interactive Mobile Companion, currently floating around the International Space Station (ISS). CIMON is the first AI to venture beyond Earth's atmosphere and into space. A voice-activated AI assistant, CIMON was created by the German Space Agency, Airbus and IBM to aid in onboard research and experimentation. CIMON is a free-flying spherical computer that joined ISS astronauts in April 2020. Its AI programs allow it to carry out tasks such as reading out instructions, researching information and taking notes on ISS experiments. CIMON's presence also reduces the stresses of working in isolation by providing social assistance. It relies on a ground-based data centre. In future developments, scientists hope to make the robot independent for missions to the Moon, Mars and beyond.



CIMON floating in microgravity aboard the International Space Station

TYPES OF AI

MACHINE-LEARNED MUSIC AND SONGS

AI can be used to master musical notes and offer a helping hand in songwriting. Companies such as Amper Music are using AI composers to create unique sounds in seconds. Note by note, Amper can be fed musical references from across all genres to assist its user on composing a new song or tune for video editing.

CHOREOGRAPHED BY COMPUTERS

Google has explored the possibility of teaching AI to dance and choreograph new routines. After analysing hundreds of hours of dance footage, the AI tool produced different potential choreography sequences to choose from. Similarly, AI-driven ballet training programs have been developed to virtually monitor and correct posture in real time.

PAINTING BY ALGORITHMS

Art has been invaded by AI through image-generation software and even a humanoid painter called Ai-Da. Created in 2019, Ai-Da uses algorithms, camera-embedded eyes and robotic arms to produce beautiful works of art. Although art is subjective and inspired, Ai-Da takes her influences from thousands of online images to generate an original work of art.

© Getty / DLR-ESA / Tesla / Ai-Da

AI BY NUMBERS

60%
Over half the world's countries use facial recognition in airports

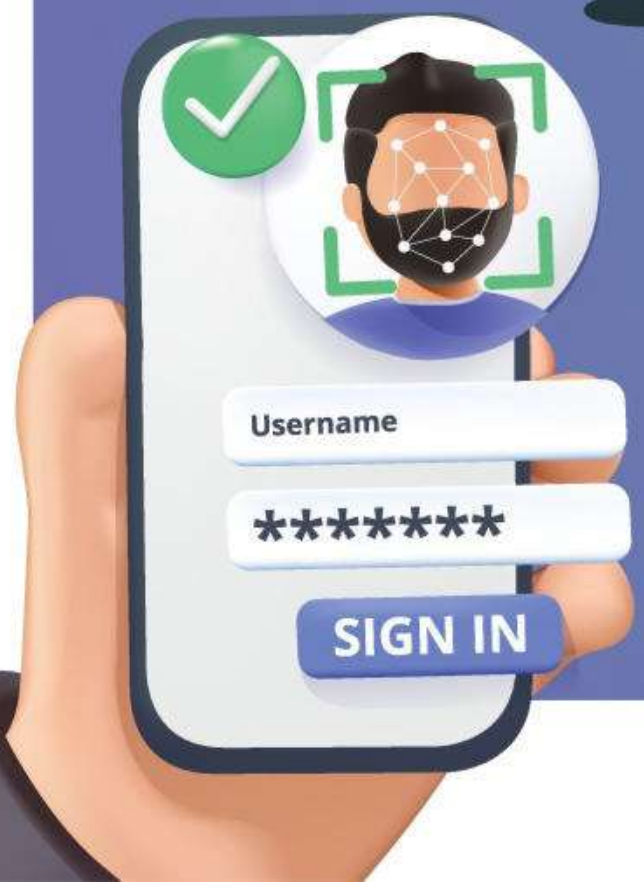
1 QUINTILLION CALCULATIONS PER SECOND
Performance of the world's fastest supercomputer, called Frontier

GAME DEVELOPERS ARE USING AI TO BUILD CHARACTERS, SUCH AS IN *ALIEN: ISOLATION*

78%
Most AI professionals are male

9 HOURS
The best AI chess player, AlphaZero, took less than half a day to play 44 million games

90%
Autonomous cars are forecasted to take up the majority of miles driven by 2035



ONE IN A MILLION
You're very unlikely to unlock someone else's iPhone using face ID

650 MILLION
AI artist DALL-E has been fed over half a billion reference images

DID YOU KNOW? AI pets are another application of the technology

175 BILLION CONNECTIONS

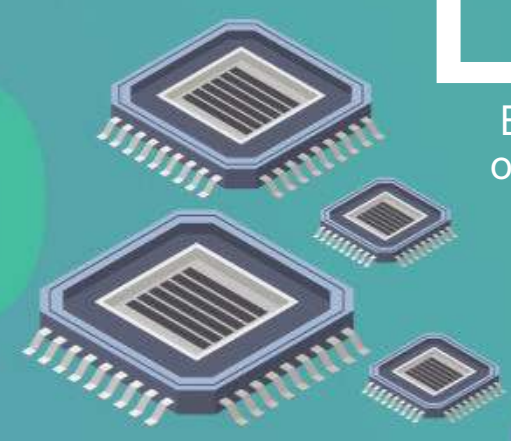
The size of GPT-3's neural network, an AI program that can produce human-like text

$267 BILLION

By 2027 the AI industry will be one of the most valuable global markets

2,880

The number of processor cores in IBM's Watson supercomputer



30 MILLION

Millions of notifications were sent to people in flood-affected areas by Google's AI warning system

24 JUNE 2021

Last year, DABUS became the first AI inventor named on a successful patent application

THREE OUT OF FOUR

Three-quarters of AI assistants have a female voice by default

IN 2000, FURBY BECAME THE FIRST AI ROBOT TOY

1.3 BILLION

By 2040 the majority of smartphones will have facial-recognition software

© Getty

BATTLEFIELD ROBOT DOGS

Meet Britain's newest four-legged mechanical soldiers

WORDS **SCOTT DUTFIELD**

Man's best friend has been given a technological upgrade and enlisted in the military. Created by Ghost Robotics and procured for the British Army by the Future Capability Group within Defence Equipment and Support, the Vision 60 is one of the latest robotic developments to find its way into the ranks. At its most basic form, the V60 is two pairs of legs to carry a myriad of payloads into the battlefield. These payloads can include a variety of surveillance cameras, such as thermal imaging and infrared, along with a robotic arm for bomb disposal and handling of harmful substances. It's even been equipped so it can be deployed by parachute.

The four-legged soldier can also be equipped with weapons and weaponised attachments. In 2021 at a Ghost Robotics annual meeting, the V60 could be seen sporting a 6.5-millimetre sniper rifle. There's also scope for larger payloads, such as anti-tank weaponry and disrupters, to be installed onto the robot's back. As a quadruped, the Ghost V60 is able to do something other terrestrial robots struggle with: navigating. Currently, autonomous robotics in the military rely on either wings or wheels to move around. However, the Ghost V60 has traded in a set of caterpillar tracks for four feet that allow it to navigate difficult terrain and urban areas.

"Imagine a scenario, let's say, in disaster relief, where the army is providing military aid to UK civil authorities or overseas," said Major David Price of future force development, part of the British Army. "If you're trying to navigate complex terrain like rubble, [the V60's] legs could enable it to manoeuvre in places that a wheeled or tracked robot may not." The V60 is able to traverse difficult or unusual terrain using a light detection and ranging (lidar) imaging system. Using lidar, the V60 can map out its surrounding area to create a 3D map of its environment and highlight any hazards or possible dangers.

Although it can detect potential hazards, the Ghost V60 cannot respond without human assistance. Unlike other military robots and drones, the V60 is not an autonomous robot, but is remotely controlled by a human operator. The purpose of these high-tech pooches is ultimately to minimise risk to humans. "If you have fewer soldiers in harmful situations, we will reduce the overall risk we expose our soldiers to," said Price. The Ghost V60 has joined the British Army's 16 Air Assault Brigade Combat Team for training and development, with the hope of it being fully fielded by 2023.

7 CONTROLLER
The V60 is controlled fully by a human operator using something that's similar to a home gaming console controller.

Did you know?
The Ghost V60 weighs 51 kilograms

British soldiers standing beside their new robotic recruits

DID YOU KNOW? Robots may make up a quarter of the British Army by 2030

The V60 is the latest robot to be trialled in the British Army

INSIDE THE V60

Get to know the newest member of the British Armed Forces

1 COMMUNICATIONS
Having both 5G and Wi-Fi gives the V60 a contingency that allows the robot to remain connected to its controller in case one connection drops out.

2 ENERGY
V60s can continuously walk at two miles per hour for 3.15 hours on their batteries.

3 EYES
Cameras at the front, rear and side of the robot give it a 360-degree view.

4 LEGS
Each of the legs has three degrees of freedom, driven by 12 motors.

5 SPEED
The V60 typically walks at around two miles per hour, but can sprint up to 6.7 miles per hour.

6 FEET
At the ends of each leg are interchangeable treads that can be configured for different environments, such as sand and ice.

SPOT THE DOG

The V60 isn't the only robotic dog that's joined military ranks. Spot is a little yellow robot dog that's been introduced into the armed forces in many nations, including the US and France. Both the V60 and Spot share dog-like quadruped locomotion and have a modular payload for a variety of cameras and sensors. This robotic companion, unlike the V60, does have autonomous capabilities. Using preplanned routes, Spot can use its onboard sensors such as lidar to navigate obstacles and tackle tough terrain. Within the military, Spot will only ever play a supportive role. Boston Dynamics, Spot's creators, prohibit the use of weaponry as a payload on the robot. Spot has recently been deployed by the United States Army to Ukraine to tackle undetonated mines and help remove mortar shells using its semi-autonomous robotic arm.

Boston Dynamics' Spot extending its flexible robotic arm

© Ghost Robotics / MOD / Boston Dynamics

HOW AIRTAGS TRACK YOUR BELONGINGS

These discreet discs keep people connected to their prized possessions

WORDS **AILSA HARVEY**

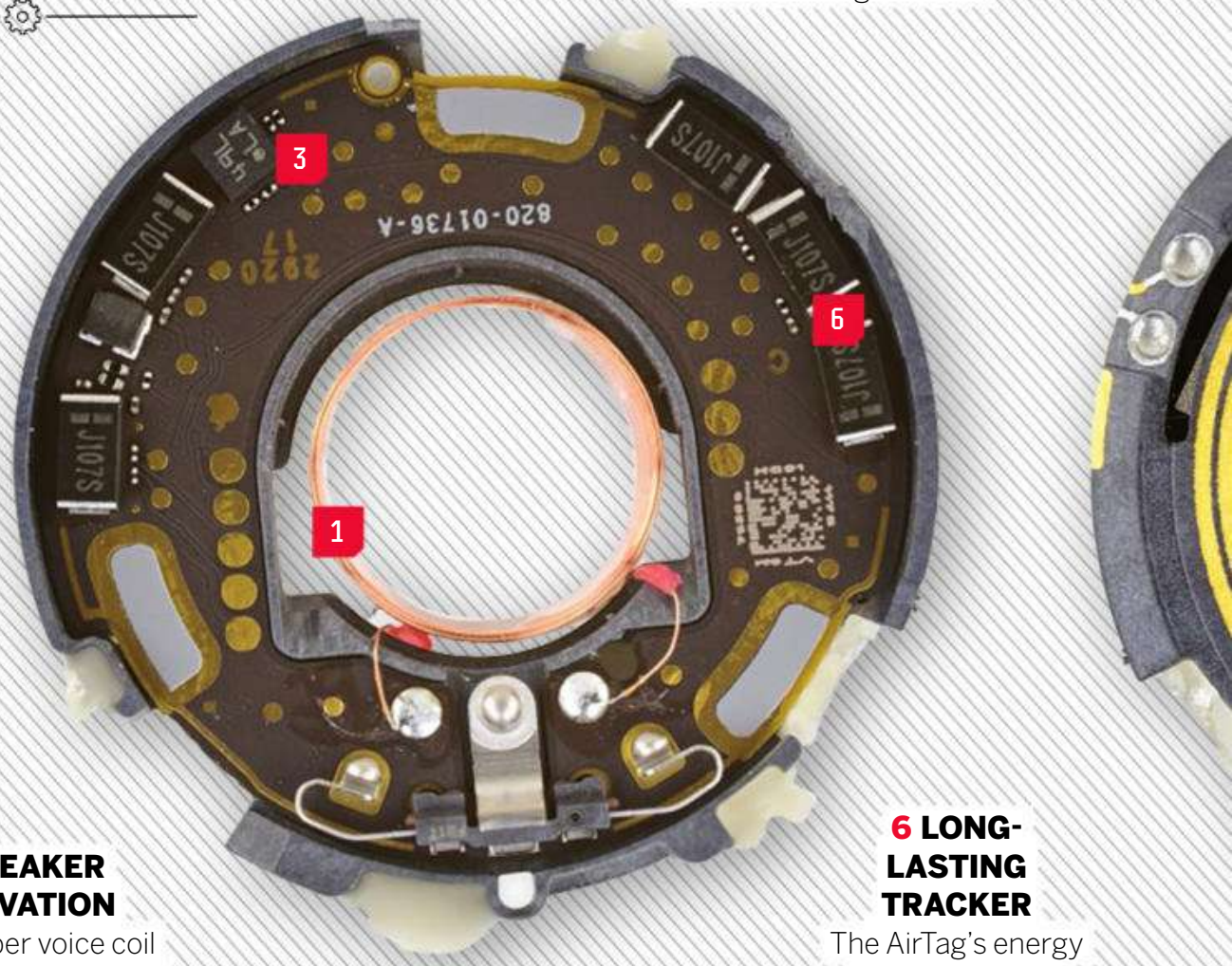
Have you ever misplaced a valuable item and been forced to retrace your steps in a long and desperate hunt for its retrieval, perhaps having no idea where to start your search? Thanks to Bluetooth technology and device connectivity, it's now possible for the exact location of a lost item to be revealed before you arrive at the destination yourself. AirTags are small trackers designed by Apple that always know where their owner's favourite items are, even if they lose sight of them.

The small circular disc is first connected to an iPhone via Bluetooth before it's attached to keys on a keychain, placed in the pocket of a bag or folds of a wallet or perhaps on the collar of a beloved pet. Each of these tags has a unique identification code which is connected to Apple's servers, as well as its own location data. This information is logged into Apple's 'Find My' application. When installed, this app will display the user's chosen icon over a map to portray the location of the AirTag.

The location of the AirTag will appear on this map when you're far away from it, or the distance between you and the tag will change in real time if you are within close range, pointing you in the right direction. If the general area of an item is known but it still can't be seen, turning on the audio setting will alert the owner to where the tag is hiding. In addition to this setting, any AirTag that has been separated from its owner's iPhone for a significant period will play a sound when it begins to move again. Not only does this help others find and report a missing AirTag, but if it's being used to track another individual, that person will be made aware and can begin the process of disabling it.

TAG TECH

What components make up an AirTag?



3 ON THE MOVE
An accelerometer detects movement and acceleration of the tag while it's being tracked.

1 SPEAKER ACTIVATION
The copper voice coil is energised to make a sound when the owner is looking for the item it's attached to.

6 LONG-LASTING TRACKER
The AirTag's energy is stored in this capacitor, which is especially designed to be long lasting.

DID YOU KNOW? To prevent AirTag stalking, a notification appears when one that isn't registered to you travels alongside your phone

HELP FROM STRANGERS

The range of some AirTags is less than ten metres, so how is it possible for someone to be reunited with their possessions if their phone can only find items lost within this range? The answer is with the help of strangers. As long as someone with an Apple device is within range, their device will receive the tag's Bluetooth signals and the location data will be transferred across the network to the connected phone. As this happens, a notification informs the owner where the AirTag was last 'seen'. The strangers whose phones help will not be alerted to the nearby AirTag, keeping the information about its whereabouts secret and not drawing unnecessary attention to it. The location data is encrypted and details about the device that led to the AirTag's reveal is always anonymous.

When Bluetooth devices have tracked down a tag, an icon will show its location on the connected phone's map

HOW BLUETOOTH WORKS

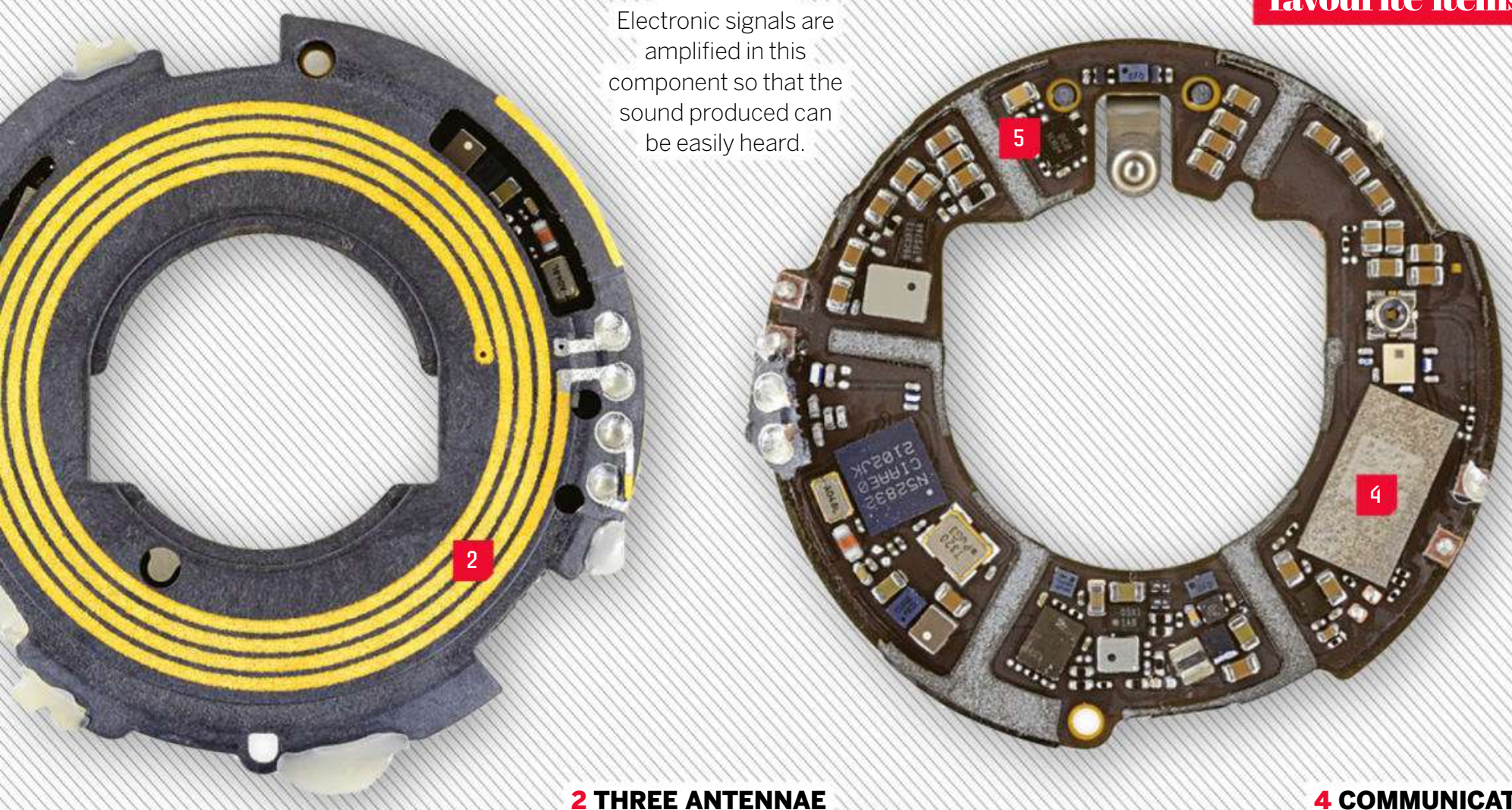
The information passed between AirTags and your smartphone relies on a wireless technology called Bluetooth. This involves the transmission of relatively weak radio waves from devices. The radio waves emitted by a mobile phone when the Bluetooth setting is turned on and those sent from the AirTag will automatically be detected by the other device. Bluetooth has 79 radio frequencies. When lost, AirTags will continuously send out a Bluetooth signal until their batteries die. As the Bluetooth signal reaches another Apple device, its strength will tell the device how far away the AirTag and attached item is. The system will use the GPS data from the device that found the tag and the Bluetooth signal to pinpoint on a map exactly where the AirTag can be reclaimed.

Bluetooth doesn't require an internet connection to work

Did you know?

You can link a maximum of 16 AirTags per phone

"AirTags are small trackers designed by Apple that always know where their owner's favourite items are"



5 AUDIO AMPLIFIER
Electronic signals are amplified in this component so that the sound produced can be easily heard.

2 THREE ANTENNAE
Bluetooth, NFC and ultra-wideband antennae are essential for the tag to communicate with another device.

4 COMMUNICATION TOOL
The transceiver can transmit and receive radio waves to and from other devices.

© Alamy / Getty / IFixit

HOW DOES CENTRAL HEATING WORK?

The hot water systems that keep your home warm and comfortable

WORDS **AILSA HARVEY**

As the winter months descend in temperate climates, returning home to a place of warmth and relaxation can become crucial. Heat doesn't come freely, however, and its production relies on the use of either gas, electricity or renewables such as solar energy. You can think of a home's central heating system almost like the circulatory system in your body, which regulates your temperature. In this comparison, the activity of your home's boiler is a bit like the chemical reactions that take place in your organs, producing heat. In a standard gas boiler, a controlled furnace is produced to heat the water that flows into it. This water is the 'blood' of the home, ready to be pumped through the walls and floors into the radiators of each room.

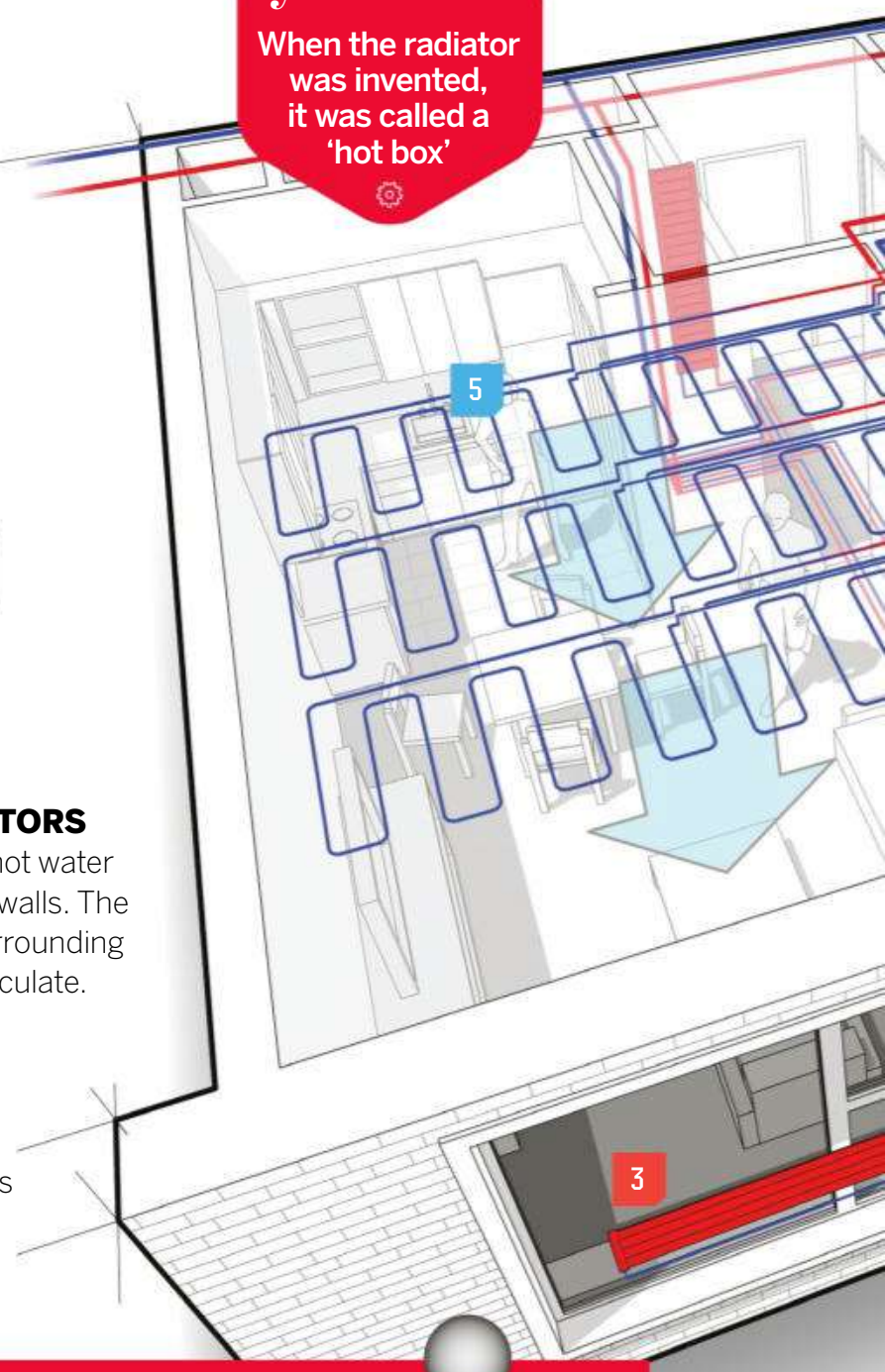
Although your body has a core temperature it needs to maintain for proper functioning, when it comes to your home, thermostats allow you to choose a personal optimum temperature for the whole house or for selected rooms. Once the set temperature is achieved, the thermostat will send a signal to the boiler to stop pumping hot water through the pipes. When the temperature falls below the setting, the boiler is alerted to turn on again. This can help people save on their energy bills, as the heating isn't left on unnecessarily.

Did you know?

When the radiator was invented, it was called a 'hot box'

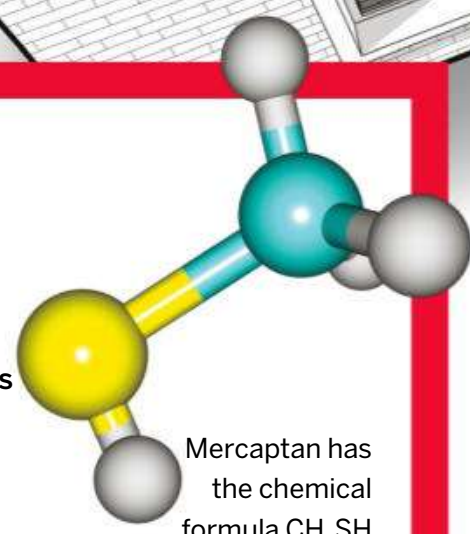
5 CEILING COOLING
In an opposite process to heating, cooled water lowers the temperature near the ceiling, making the air drop downwards.

3 ROOM RADIATORS
Radiators bring the hot water from pipes inside the walls. The radiator heats the surrounding air, causing it to circulate.



WHAT DOES GAS SMELL LIKE?

If you have a leak in your central heating system, you're likely to smell a strong odour. But naturally the gas has no colour or scent. You might compare the smell of leaking gas to eggs or cabbage, and this is due to the addition of a chemical called mercaptan. Gas companies add mercaptan to gas so that you notice a leak before harmful concentrations accumulate that can lead to an explosion. The sulphur that makes up the mercaptan compound gives gas its distinctive smell.



Mercaptan has the chemical formula CH_3SH

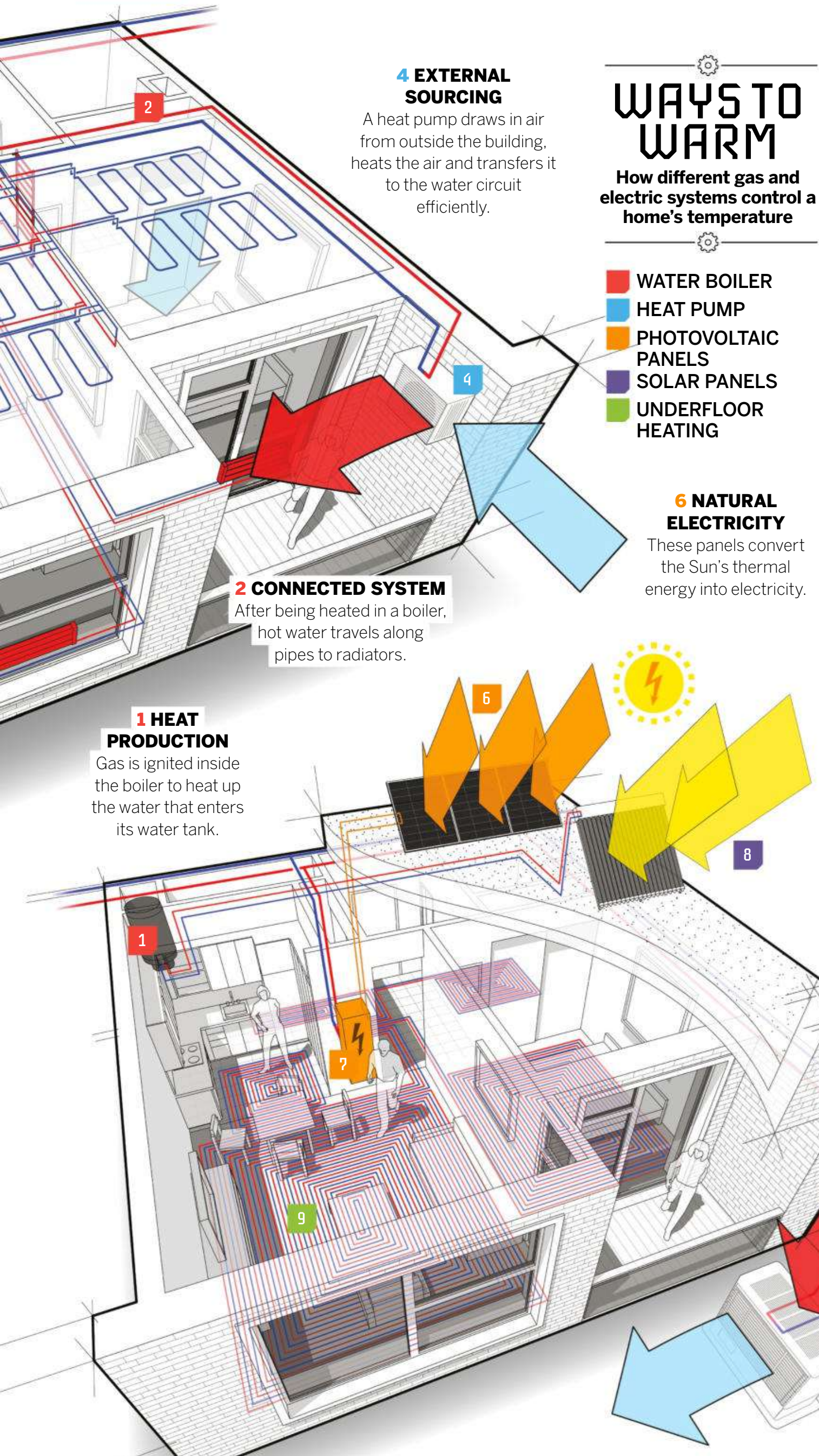
Smart thermostats use WiFi to automatically adjust heating

DID YOU KNOW? Natural gas was first used to heat homes in China in 500 BCE

WAYS TO WARM

How different gas and electric systems control a home's temperature

- WATER BOILER
- HEAT PUMP
- PHOTOVOLTAIC PANELS
- SOLAR PANELS
- UNDERFLOOR HEATING



4 EXTERNAL SOURCING
A heat pump draws in air from outside the building, heats the air and transfers it to the water circuit efficiently.

6 NATURAL ELECTRICITY
These panels convert the Sun's thermal energy into electricity.

2 CONNECTED SYSTEM
After being heated in a boiler, hot water travels along pipes to radiators.

1 HEAT PRODUCTION
Gas is ignited inside the boiler to heat up the water that enters its water tank.

7 ELECTRIC BOILER
The electrical energy generated by photovoltaic panels can be used to heat water in the house's central heating system.

8 SOLAR HEATING
These panels convert the Sun's solar radiation into heat energy that can be used directly for central heating.

9 UNDERFLOOR
A dense network of thin pipes beneath an entire floor can heat a room more evenly than radiators.

AN ANCIENT INVENTION

The technology used today to heat an entire home is relatively simple – a fast process that sometimes requires just the touch of a button. But its origins date back to 350 BCE, when ancient Greeks used underfloor fires to heat temples. Called a hypocaust, meaning 'under burnt', this system was later used extensively in Roman homes. House floors were raised on pillars to create space for the warm air to spread, while the walls of these old homes were built with hollow bricks. As warm air and smoke were released at the tops of houses, warmer air was drawn through the walls to disperse it over multiple floors. Unlike modern systems, the early hypocaust was extremely laborious and required someone to work continuously, refuelling the fire.

This Roman villa's collapsed floor reveals the pillars used in a hypocaust system

© Alamy / Getty

THE POWER OF PASTEURISATION

How the process of preheating our food keeps us safe from deadly germs

WORDS **SCOTT DUTFIELD**

The process of pasteurisation is a centuries-old method of preparing food, giving it a longer life in larders and today on supermarket shelves. Since the 11th century, people have been using heat to battle against microorganisms to preserve their food. Ancient Chinese wine makers used hot clay jars to heat wine before burying them in cool soil to preserve them. However, it wasn't until the late-19th century that a name was attributed to this process.

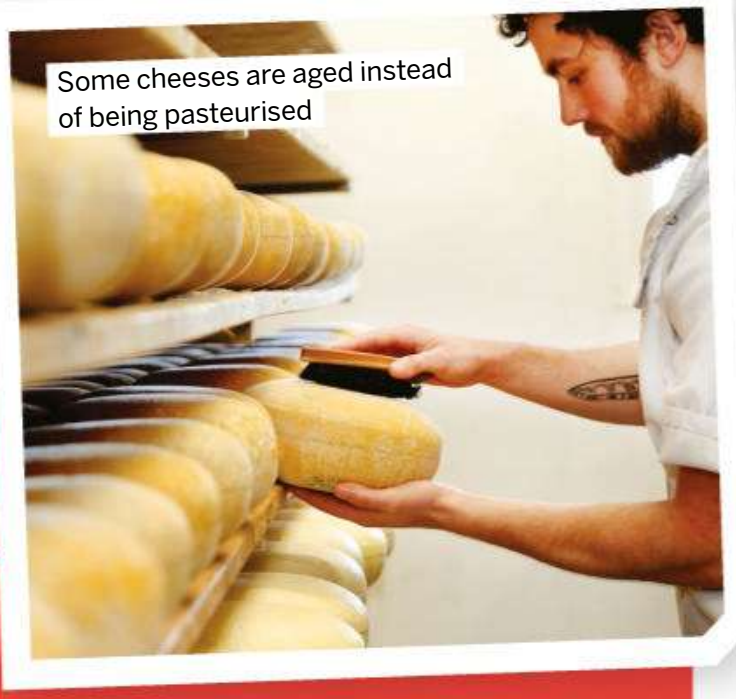
Pasteurisation is used to combat the harmful pathogens that reside within raw foods, often referred to as spoilage microorganisms. These can be transferred to our bodies when we consume these foods in their raw state. Pathogens such as *E. coli* and *Salmonella* can be found in raw milk, and when ingested can cause serious health issues. To destroy and remove harmful pathogens from certain foods, such as milk, it's heated to high temperatures below 100 degrees Celsius. The heat denatures and breaks down the proteins and enzymes within the pathogens, killing them and allowing humans to consume it without the risk to their health. Once a food has been heated, it's then cooled down and stored. Storing pasteurised products in cold conditions like a fridge creates an environment where microorganisms are unable to reproduce and grow, which would effectively undo the job of pasteurisation.

Did you know?

***E. coli* cells double every 20 minutes**

This process doesn't completely sterilise the food product, but does remove enough of the spoilage microorganisms that it's safe to eat and extends its life span. Other than killing harmful pathogens, studies have found that pasteurisation can slightly change the vitamin concentration in some products. In

DID YOU KNOW? There are around 270 million cows producing the world's supply of milk


Some cheeses are aged instead of being pasteurised

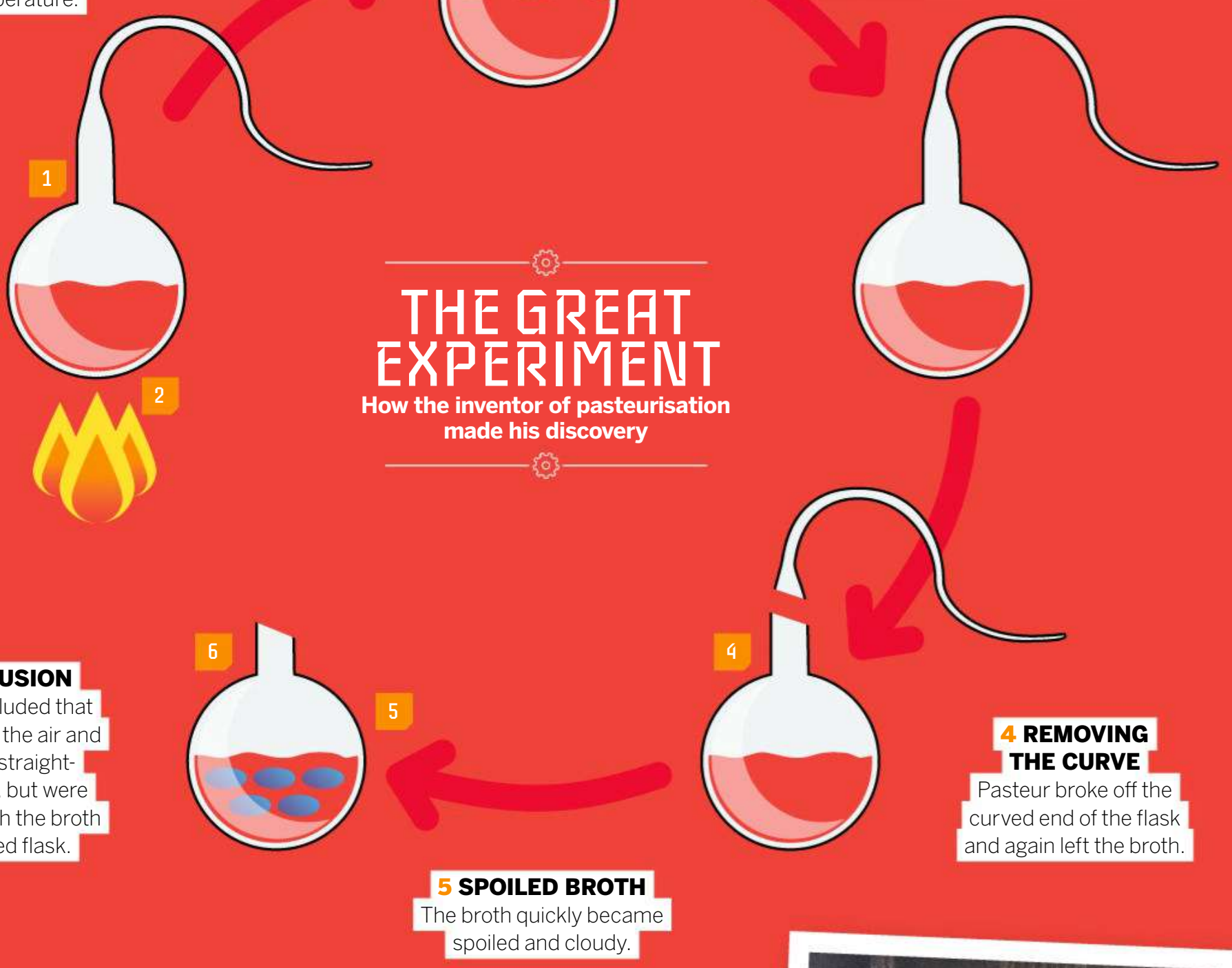
THE GREAT EXPERIMENT

How the inventor of pasteurisation made his discovery

1 SETTING UP
Pasteur placed meat broth into a swan-necked flask.

2 BOILING
The broth was then boiled to kill any germs and allowed to cool to room temperature.

3 LEFT TO SPOIL
Untouched for several weeks, Pasteur observed that the broth hadn't changed in the curved flask.



4 REMOVING THE CURVE
Pasteur broke off the curved end of the flask and again left the broth.

5 SPOILED BROTH
The broth quickly became spoiled and cloudy.

6 CONCLUSION
Pasteur concluded that germs were in the air and fell into the straight-necked flask, but were unable to reach the broth in the curved flask.

PASTEUR THE PIONEER

The word 'pasteurisation' comes from the man who discovered it in 1865. Louis Pasteur, a French chemist and microbiologist, invented and patented the process after studying the science behind fermentation and attempting to tackle the 'disease' of wine, which was destroying vineyards in France. Having discovered a microbe that converts alcohol into vinegar, called *Myoderma aceti*, and publishing his 'germ theory' in 1861, Pasteur was tasked by Napoleon III to understand the disease that was turning wine into vinegar. By experimenting with foods that had been exposed to the air following a period of heating and those that had not, Pasteur theorised that germs in the air were responsible for the spoilage of certain foods and wine. He discovered that heating wine to a temperature above 55 degrees Celsius killed microorganisms and extended the wine's life before it spoiled.

A painting of Louis Pasteur experimenting in his laboratory

©Getty

Eggs in the United States being pasteurised to remove potential *Salmonella*

milk the process increases the concentration of vitamin A but decreases the levels of vitamin B12 and E. Some forms of pasteurisation occur long before the food has even been made, such as in eggs. In 2017, the Food Standards Agency updated its advice around eggs, allowing the consumption of raw eggs or slightly cooked eggs produced under British Lion Code. Eggs produced under this code come from chickens that have been vaccinated against *Salmonella*, therefore reducing the risk of transferring the bacteria. Eggs produced outside of the Lion Code are not suitable for raw eating and should be completely cooked before consuming.

While a majority of foods, such as milk, cheese, nuts and wine, are pasteurised and safe to consume, there are alternatives made from unpasteurised products that are safe to eat. Many soft cheeses are made with unpasteurised or raw milk, but instead of undergoing pasteurisation, this type of cheese is required to be aged at a constant temperature to stunt the growth of harmful bacteria. In Canada the law requires cheese to be aged for at least 60 days at two degrees Celsius before it can be sold.

Did you know?

420,000 people die a year from eating contaminated food

Typically, the process of pasteurisation requires a constant refrigeration temperature to prevent the growth of spoilage microorganisms, but that's not always the case. Milk that sits in cartons unrefrigerated is known as ultra-high temperature (UHT) milk. This extreme version of pasteurisation involves rapidly heating the milk to temperatures of at least 135 degrees Celsius and then rapidly cooling it to room temperature. This process kills all of the pathogens in the milk, essentially sterilising it, and is packaged in an aseptic container to prevent the growth of any new bacteria. The treated milk can then be stored without the need for refrigeration and can last for months. Although traditional methods of pasteurisation remain the predominant way that dairy products and other perishables are treated, there are emerging non-heat processes, such as High Pressure Processing (HPP) and Pulsed Electric Fields (PEF), that are being explored as an alternative option. PEF foods at ambient temperatures are exposed to pulsing electric fields that neutralise spoilage microorganisms, whereas HPP uses extreme pressure to make spoilage microorganisms inactive and extend the product's shelf life.

Inside a milk pasteurisation plant

"This process doesn't completely sterilise the food product"

PASTEURISED PRODUCTS

Fruit juices

Beer and wine

Imitation meats

Nuts

Flour

Eggs

Dairy products

Honey

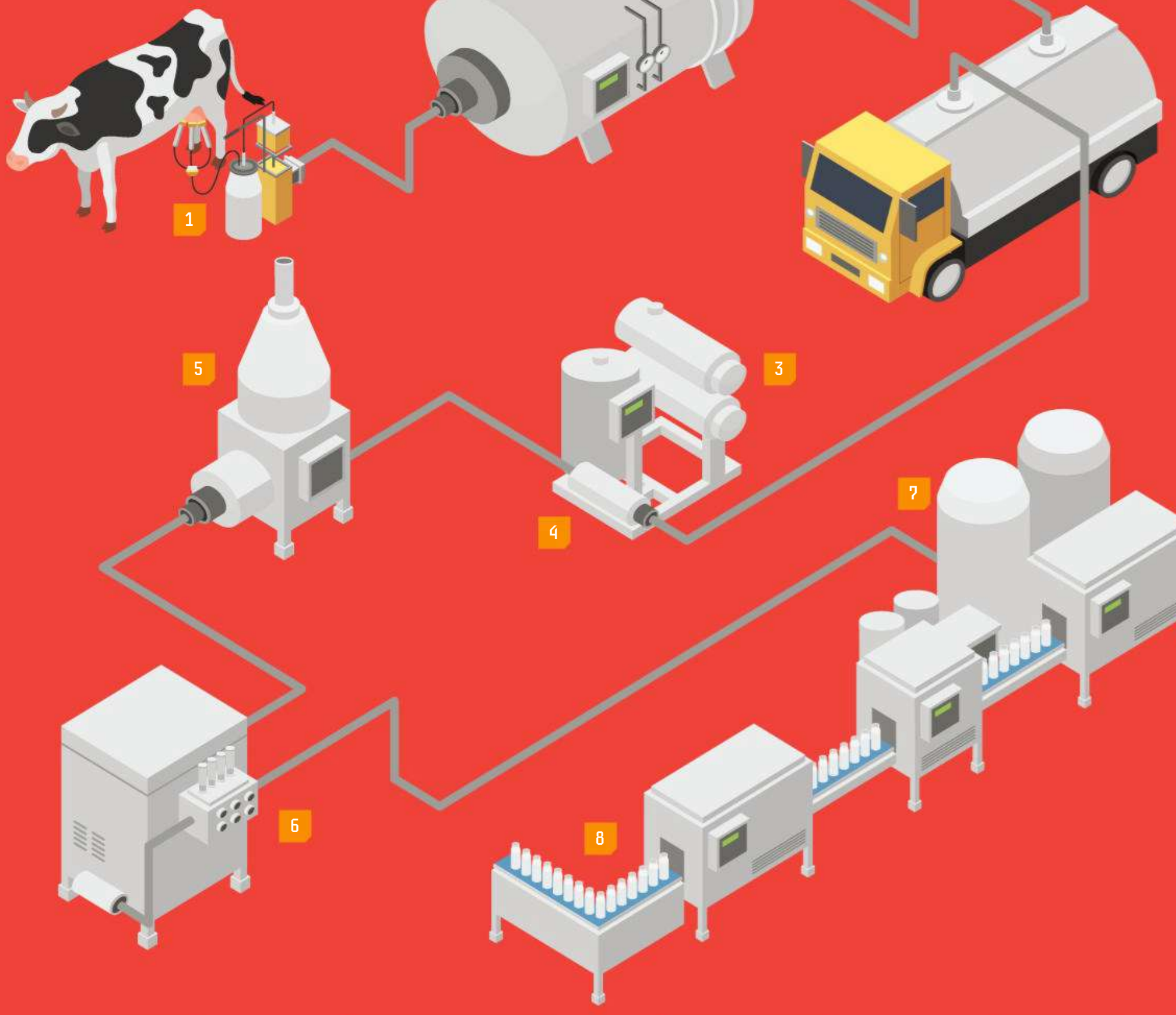
Vinegar

Crab meat

DID YOU KNOW? In 2021, Europe produced the most cow milk in the world – almost 145 million tonnes

MAKING MILK

The stages that make milk safe to drink



1 MILKING
A single dairy cow can produce around 28 litres of milk per day, which is extracted via vacuum cups attached to the udders.

2 TEMPERATURE
Milk is typically heated to around 74 degrees Celsius for 20 seconds.

3 PASTEURISATION
Milk-filled pipes are surrounded by water at two different temperatures – one to heat the milk and the other to cool it back down to four degrees Celsius.

4 DESTRUCTION
The proteins and enzymes in spoilage microorganisms are denatured and broken down, ultimately killing them.

5 SEPARATION
Milk is spun to separate and remove fat to make the variety of milks on store shelves, such as semi-skimmed.

6 HOMOGENISATION
Pressure is applied to the milk to prevent cream separation and to blend the mixture together.

7 STORAGE
Pasteurised milk is transported and stored at five degrees Celsius or less.

8 BOTTLING
Pasteurised milk is packaged into sterilised bottles or cartons and stamped with an expiry date of up to two weeks.

© Alamy / Getty

LIGHTNING ROD PROTECTION

How these vital structures found on tall buildings alter the path of lightning

WORDS AILSA HARVEY

A bolt of lightning is a fleeting yet extremely powerful shot of electrical charge through the sky. Appearing like a dagger aimed at Earth, these strikes of energy are simply a redistribution of electrical charge. But if you're in the wrong place at the wrong time, they can be extremely damaging. If a building is struck by lightning, there's a high risk of fire as millions of volts of zap a building's electrical system.

Another threat from lightning to a building is the impact of the resulting shock waves. As lightning rapidly heats the air, it produces shock waves along its path. These have enough energy to damage a building's strong concrete and brick. To protect you, your home and other buildings from this potential destruction, lightning rods can control the path of these electrical charges.

These are large metal rods that extend beyond the highest point of a building and into the ground below. This direct pathway, made of a conductive material, ensures that the lightning is attracted to the rod first and bypasses the rest of the building. Although we don't have the ability or technology to know exactly when and where lightning will strike, with lightning rods we can force it to follow the least damaging route around vulnerable structures.

Did you know?

One lightning strike can carry 300 million volts

WHEN WERE THEY INVENTED?

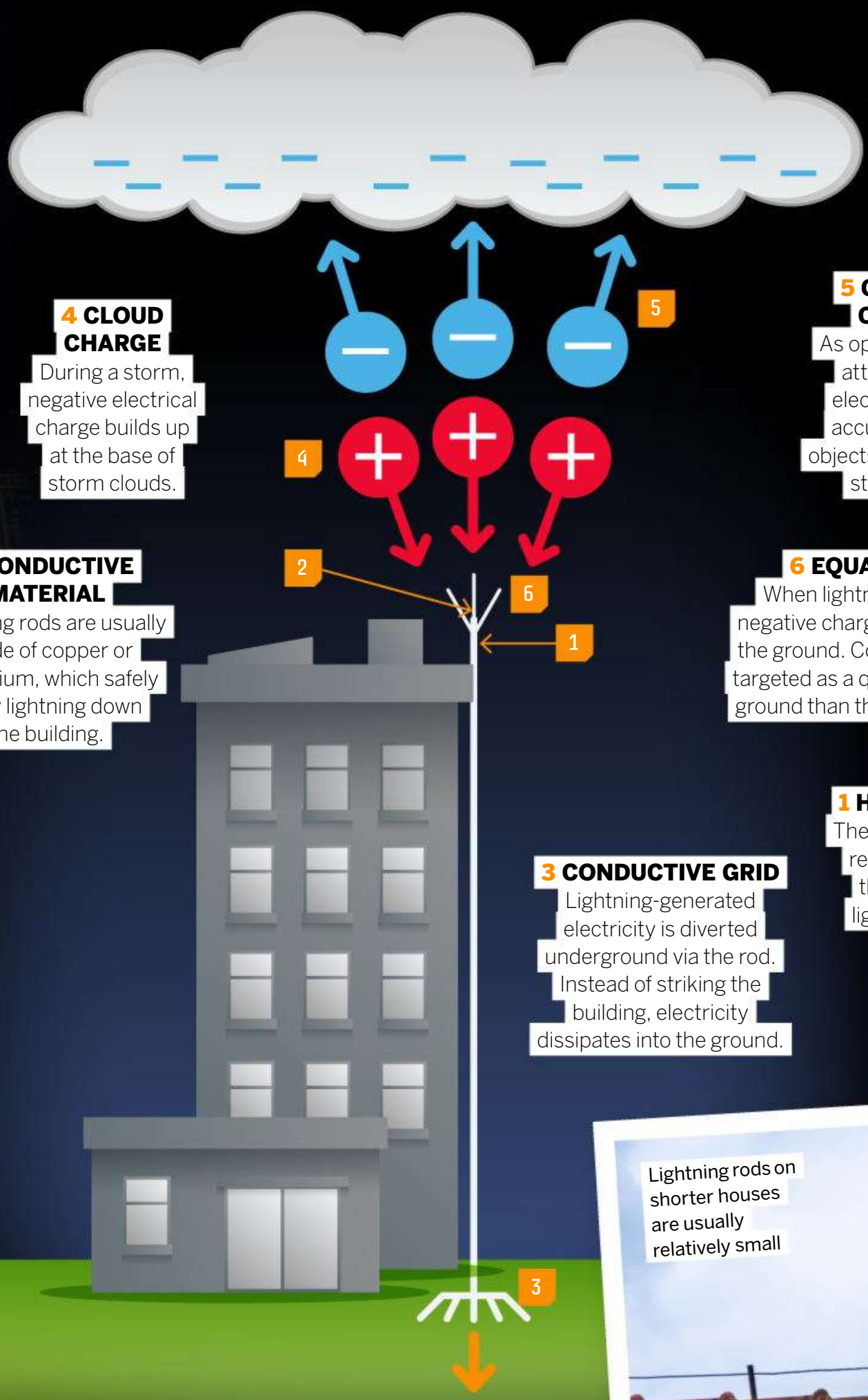
The inspiration for the invention of lightning rods came in the 18th century, when scientist and Founding Father of the United States Benjamin Franklin was flying a kite during a storm. After lightning struck and burned the kite, Franklin began to research how to attract lightning and control its path. In 1752 he added a metal key to his kite and discovered that the lightning would travel down to the metal key. This proved the attraction of lightning to metal, and because the discharge of electricity stopped at the metal, it served as protection for the surrounding materials. One year later, Franklin put his findings to practical use when the first metal lightning rods were installed in the US.

Benjamin Franklin wrote about the kite experiment in a letter to his friend

DID YOU KNOW? The Empire State Building was once struck by lightning eight times in 24 minutes

FROM CLOUD TO GROUND

How lightning rods shield buildings from strikes


4 CLOUD CHARGE
During a storm, negative electrical charge builds up at the base of storm clouds.
5 CHANGING CHARGES
As opposite charges attract, positive electrical charges accumulate in the objects below negative storm clouds.
2 CONDUCTIVE MATERIAL
Lightning rods are usually made of copper or aluminium, which safely carry lightning down the building.
6 EQUALISATION
When lightning strikes, the negative charge rushes towards the ground. Conductive metal is targeted as a quicker route to the ground than the air or a building.
1 HIGH POSITIONING
The top of the rod needs to reach above the roof so that it's closest to the lightning and serves as a target point.
3 CONDUCTIVE GRID
Lightning-generated electricity is diverted underground via the rod. Instead of striking the building, electricity dissipates into the ground.
5
4
2
6
1
3

The Empire State Building's lightning rod is hit between 25 and 100 times a year

5 FACTS LIGHTNING STRIKES

1 LIGHTNING SPEED
It would take 55 minutes for a lightning strike to travel from Earth to the Moon.

2 HIGH ACTIVITY
Lake Maracaibo in Venezuela is struck by lightning up to 28 times a minute for nine hours every day on average – more than any other place on Earth.

3 STRIKINGLY COMMON
Around the world there are about 3 million lightning strikes every day, resulting in 1.4 billion a year.

4 INTENSE HEAT
As the built-up electric charge travels down the thin path of a lightning bolt, its temperature can reach five times that of the Sun's surface, at nearly 30,000 Celsius.

5 NATURAL GLASS-MAKING
When lightning hits sand, it can cause the grains to meld together into a glass-like material.

Lightning rods on shorter houses are usually relatively small

©Getty

KETCHUP SCIENCE

Unbottle the chemistry of this popular condiment and the physics behind its flow

The first squeezable ketchup bottles were made in 1983

WORDS **AILSA HARVEY**

Ketchup has existed since 1812 and has become many people's favourite condiment as a sauce or dip. Its combination of sweet, savoury, salty and tangy flavours make it a match for a variety of savoury foods. But what is this tomato-based sauce?

Ketchup is neither a solid or liquid, as its ability to flow onto your plate changes based on its conditions. Instead it's a non-Newtonian fluid, also known as a 'soft solid'. Being a combination of solid tomatoes in liquid, ketchup will only move when enough force is applied to it. When left alone, the solid and liquid components will eventually separate inside the bottle – this is what causes an unsatisfying watery liquid to sometimes drip out of an old bottle of ketchup onto your chips. To reproduce the right mixture, you need to 'shear thin' it. This will increase the viscosity of the solid ingredients that settle in the bottom of the bottle by shaking it to reintroduce the liquid back into the mixture.

Did you know?

Ketchup should flow out a bottle at a speed of 0.028 miles per hour

One of the most popular ketchup-producing companies is Heinz. When founder Henry Heinz began to sell ketchup in 1876, he chose to produce transparent glass bottles to show consumers that the contents were fresh. However, this inflexible container made it difficult for ketchup fans to manipulate the sauce and get it flowing. Today ketchup is also sold in squeezable plastic containers that make it easier for consumers to recombine the solids and liquids within.

FRUIT TO BOTTLE

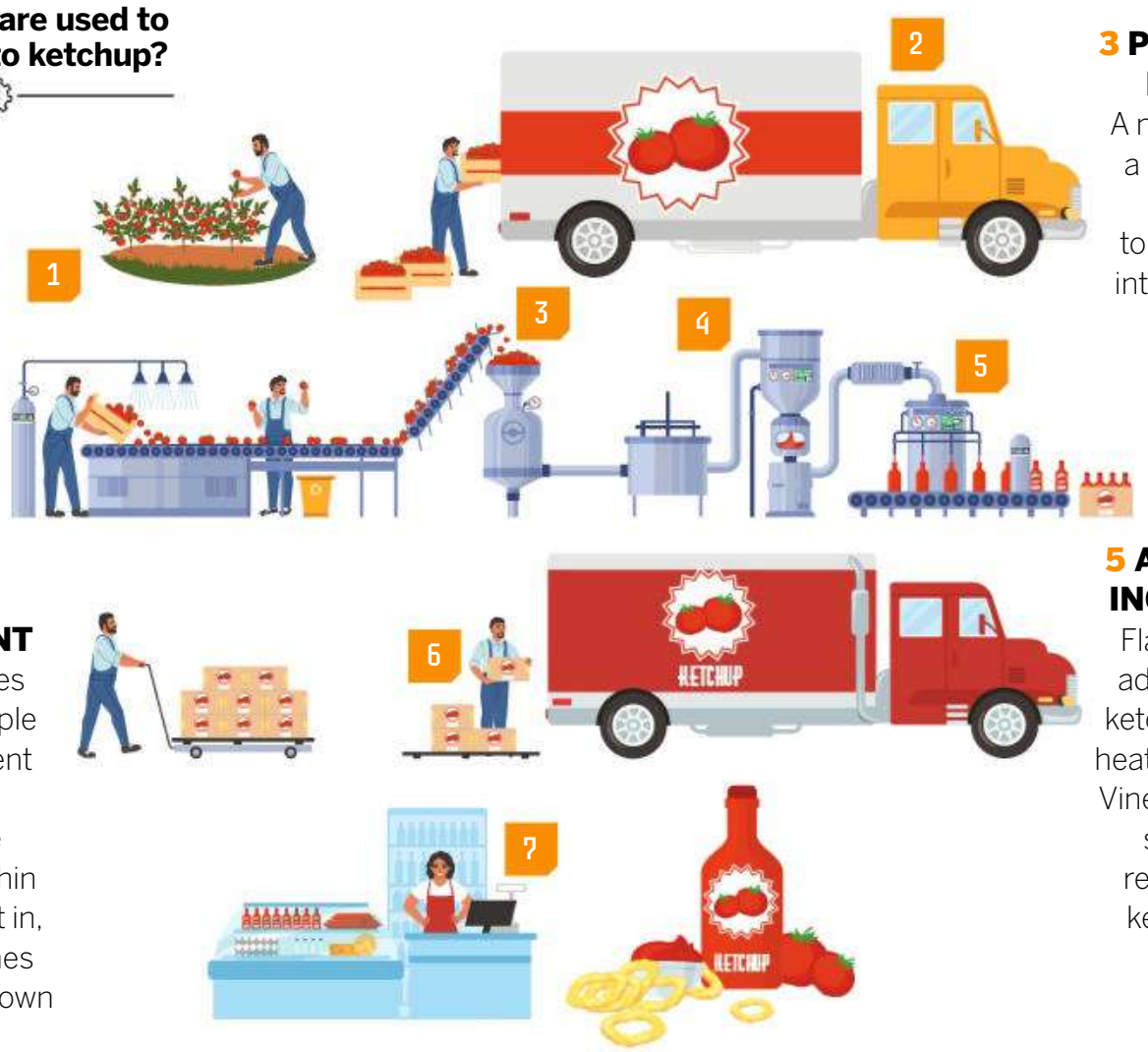
What methods and ingredients are used to make tomato ketchup?

1 HARVESTING TOMATOES

Because tomatoes are mostly water, 148 grams of tomatoes are required to make 100 grams of Heinz ketchup.

2 TRANSPORTATION

Tomatoes picked for ketchup are largely grown in America, Italy and China.



3 PULVERISING MACHINE

A machine called a homogeniser breaks the tomatoes down into a consistent mixture.

4 HEAT TREATMENT

The tomatoes endure multiple heat treatment steps to deactivate enzymes within the fruit. If left in, these enzymes would break down pectin, a carbohydrate that holds cells together and keeps ketchup thick.

5 ADDITIONAL INGREDIENTS

Flavourings are added while the ketchup is further heated for cooking. Vinegar, sugar and salt are also responsible for ketchup's long shelf life.

6 DELIVERY

After being bottled and boxed, ketchup is transported worldwide. In Japan it's used as a pasta-sauce substitute. Some in Eastern Europe cover pizzas with it and in Canada it's even added to cakes.

7 MILLIONS OF SALES

Around 650 million ketchup bottles are sold by Heinz alone every year.

THE PERFECT POUR

1 SHAKE

The solid ingredients may have sunk to the bottom of the bottle, leaving a watery upper layer. Shaking the bottle will recreate an even consistency.

2 INVERT

If the bottle isn't full, turn it upside down and shake it downwards once, forcefully. This will accelerate both the bottle and its contents. The ketchup will accumulate at the neck of the bottle.

3 POUR OR SQUEEZE

Open the bottle and gently pour or squeeze, depending on the bottle type. The contents should be mixed well and flow out of the container smoothly.

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SPORT

TECH

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SEE INSIDE A SEGWAY

How these two-wheeled vehicles let you glide smoothly over terrain

WORDS **AILSA HARVEY**

This fully electric vehicle could be mistaken for a giant scooter. What sets a Segway apart is that it's the first self-balancing two-wheeled vehicle. Although the rider of a Segway will need to move their body to navigate paths and roads, the mechanisms within the Segway automatically prevent it from falling over – even when you lean far forward. Leaning is the key movement when operating a Segway, most of which can travel up to 12 miles per hour. To accelerate forwards you must move your weight gently towards the front of the vehicle while keeping your feet still and holding onto the handlebars. When braking you should lean back into an upright position, and to reverse gently pull yourself backwards.

A technique called 'dynamic stabilisation' causes the vehicle to match the actions of its rider's body. As they lean forward, the speed of the wheels' rotation needs to match the movement of the action. The Segway's sensors evaluate the position and weight distribution of the rider, then send signals to the computer 100 times per second to make sure that no slight movement is missed. Leaning forward tilts the Segway and causes its motors to rotate the wheels forwards, while leaning backwards does the opposite. To steer, the handlebars need to be pushed left and right. When travelling, this action will cause one motor to turn faster than the other, turning the vehicle. At a standstill this action moves the two wheels in opposite directions to rotate the Segway on its axis.

What makes the Segway so satisfying to use is that this quiet electric technology works with the body to create a natural feeling of control. By using your core, arms and legs to manipulate the vehicle, you may feel half-human and half-robot as you cruise along tracks and pathways.

Organised Segway tours are a popular way for tourists to explore new locations

Did you know?

Segway Inc was founded on 27 July 1999

9 MOTOR

The battery powers two electric motors on each side of the Segway. These can move the wheels independently of each other.

6 SELF-BALANCING

Within the Segway's computer, gyroscopic sensors measure the speed of rotational movement from its axes to maintain balance.

SELF-BALANCING TRANSPORTATION

The Segway was the creation of American inventor Dean Kamen. Prior to this, Kamen released the iBOT, which looked like a standard wheelchair but had two sets of powered wheels at the rear that could rotate over each other when the vertical movement was initiated by the user or assistant, thus able to carry the wheelchair user up and down stairs. It was the balancing mechanism and tilt sensors in this invention that led to the Segway.

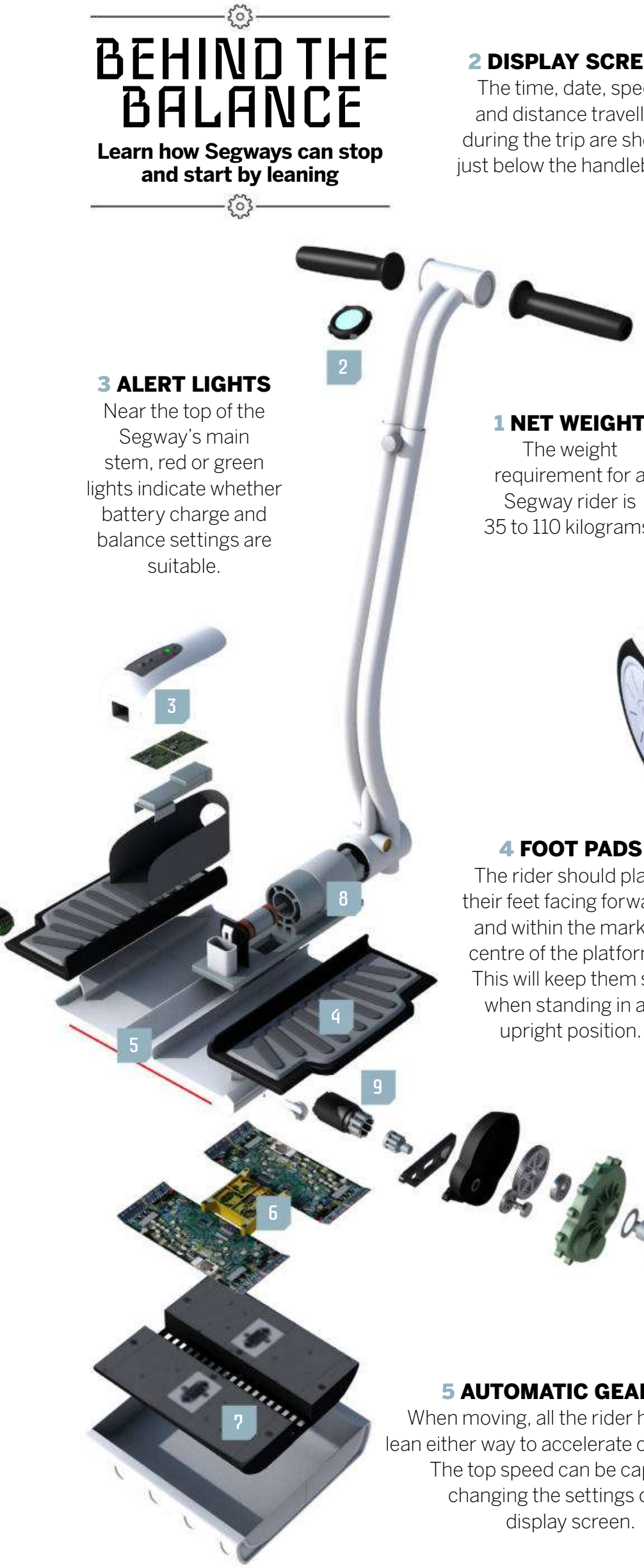
Kamen believed that Segways could overtake cars as the main form of transport, limiting traffic jams in the process. In an interview, the inventor said that Segways "will be to the car what the car was to the horse and buggy". Although this didn't happen after critics analysed the safety of Segways on the roads, they were being used across golf courses, by tour guides and law enforcement agencies by 2005. However, in 2020 the manufacturer stopped producing Segways due to high numbers of reported accidents. Some well-known figures involved in incidents include former US president George Bush, who fell off one, and Jamaican athlete Usain Bolt, who was hit by a Segway-riding cameraman during an event.

Dean Kamen demonstrating the iBOT wheelchair

DID YOU KNOW? ‘Segway’ comes from the Italian word ‘segue’, meaning ‘smooth transition’

BEHIND THE BALANCE

Learn how Segways can stop and start by leaning



2 DISPLAY SCREEN
The time, date, speed and distance travelled during the trip are shown just below the handlebars.

3 ALERT LIGHTS
Near the top of the Segway’s main stem, red or green lights indicate whether battery charge and balance settings are suitable.

1 NET WEIGHT
The weight requirement for a Segway rider is 35 to 110 kilograms.

4 FOOT PADS
The rider should place their feet facing forwards and within the marked centre of the platforms. This will keep them still when standing in an upright position.

8 TILT MECHANISM
Called the base rocker, this component twists as the handlebars are moved left and right. The amount of movement is measured by the Segway’s computer to turn the vehicle at the appropriate angle.

5 AUTOMATIC GEARBOX
When moving, all the rider has to do is lean either way to accelerate or decelerate. The top speed can be capped by changing the settings on the display screen.

7 BATTERIES
The iron and lithium batteries can both work alone to power the Segway. This means that if one fails, the Segway remains in control.

10 WHEELS
The tyres are equipped with guards on both sides to shield from mud and protect legs from coming into contact with the moving wheels.

5 SEGWAY APPLICATIONS

1 SECURITY
Police and security guards use them to slowly and safely patrol an area. These fast, narrow vehicles allow them to quickly respond to an incident and navigate crowds well.

2 LOGISTICS
Carrying platforms can be added to the fronts of Segways to make them an ideal vehicle for carrying items efficiently in warehouses and factories.

3 MOBILE ROBOTS
When combined with robot technology, Segways can travel autonomously. Sensors are used like eyes to follow objects, while the robot only needs to lean forwards and backwards slightly to adjust speed.

4 MOBILE RESCUE
When paramedics need to reach a scene on foot, Segways provide a speedier alternative. This reduces the time it takes them to reach critical injuries and makes carrying medical supplies much easier.

5 PRIVATE TRANSPORT
Segways are eco-friendly and energy efficient, making them a favourite commuting vehicle for some. These Segways are more popular in urban areas.

© Getty / Illustration by Adrian Mann

LIFE-SAVING CRASH HELMETS

How headgear limits injuries and saves lives during small falls and serious crashes

WORDS **AILSA HARVEY**

Injury to the head is the leading cause of death in motorcycle crashes, but wearing a helmet reduces the chances of sustaining such an injury by 65 per cent. In many countries, it's against the law to ride a motorcycle without a crash helmet. Motorcyclists are much more exposed to the hazards of the road because they aren't contained within the steel shell of a car, so their heads need direct protection.

Helmets protect the brain and head during a crash by cushioning the impact. The human brain controls a person's thoughts, memories, emotions and even their movement and ability to ride a motorcycle in the first place. Motorcycle crashes commonly result in traumatic brain injuries, which is the term given to a sudden and violent impact on the brain. This can be in the form of a temporary concussion, sometimes causing the rider to lose consciousness for any time from a few minutes to a few hours and often leading to temporary confusion and disorientation. Other brain injuries are much more severe and reduce a person's mobility for life. Motorcyclists are four times as likely as car passengers to suffer a road injury.

Did you know?

The first motorcycle helmet was invented in 1914

Helmets are essential in lowering these injury statistics. The type and thickness of the material is chosen to reduce the impact forces that are transferred to the brain. If the helmet retains some of the impact energy that's produced in a collision, the movement of the skull inside the helmet is reduced, as is that of the brain in the skull.

Full-face helmets weigh between 1,400 and 1,800 grams

1 OUTER SHELL
This layer is first to be impacted. It's usually made of hard polycarbonate plastic or synthetic fibres such as kevlar or carbon fibre.
2 IMPACT-ABSORBING LAYER
Expanded polystyrene foam lines the outer shell. When the helmet is hit, the foam absorbs much of the impact energy.
5 CHIN STRAP
This fastens under the chin, helps hold the helmet in place and keeps the head protected even when a crash knocks the driver from an upright position.
5

PUTTING THEM TO THE TEST

During manufacturing, crash helmets are tested to ensure that they're strong enough to protect the brain and skull without obstructing the user's vision. A fine compromise needs to be achieved to cover a large area of the head with protective material and padding while also achieving maximum visibility through the visor so that riders can better avoid obstacles and quickly react to events in their peripheral vision.

Destructive tests are some of the most crucial, analysing how a helmet responds to being dropped, crushed and punctured with sharp objects. Meanwhile, abrasion tests involve sliding the helmet across a surface with significant force to measure how much it causes the neck of the person wearing it to twist. This movement should be avoided as much as possible because it can cause spinal injuries.

Visors are essential for protecting eyes from the Sun's rays

DID YOU KNOW? In 2017, crash helmets saved the lives of 1,872 people in the US

SHOCK-ABSORBING SCIENCE

A layered crash helmet reduces the impact of an accident

6 VISOR
An eye and face shield stops debris from entering the helmet and helps drivers keep their eyes open and focused on the road.

7 MOUTHPIECE
A vent near the mouth stops the driver's breath from fogging up the helmet.

3 SOFT PADDING
Cushioning foam and soft fabric are in direct contact with the rider's head. This provides comfort and keeps sweat off the face.

4 CHEEK PADDING
For extra comfort, and to hold the helmet in place, cheek pads press against the sides of the face.

> "Motorcyclists are four times as likely as car passengers to suffer a road injury"

5 HELMET STYLES

1 FULL FACE
This type of helmet fully encloses the biker's head down to the base of the skull, including the chin and face.

2 MODULAR
The section that covers the chin is separate, allowing the wearer to move it up and down based on how much coverage is needed.

3 OFF-ROAD
The chin bar extends further from the rider's face for better circulation of air during more strenuous activities.

4 OPEN FACE
In warmer climates, full-face coverage can be extremely uncomfortable, so helmets with no chin bars are more popular.

5 HALF HELMET
These helmets have limited coverage, only protecting half the head. For this reason they are illegal roadwear in some countries.

© Alamy / Getty / Illustration by Nicholas Forder

DID YOU KNOW? Khufu was the second pharaoh of the Fourth Dynasty and died around 2566 BCE

SECRETS OF THE PYRAMIDS

Has the monumental mystery of their construction been solved at last?

WORDS **DAVID WILLIAMSON**

Rising majestically to almost 140 metres above the Egyptian desert, the Great Pyramid of Khufu at Giza – the last remaining wonder of the ancient world – still stands tall in mysterious silence after more than 4,500 years. Over the centuries, its untold secrets have inspired curiosity, awe and bewilderment in equal measure. As a testimony to the skills of an ancient civilisation, it has no equal.

For years, the Great Pyramid has been at the centre of a long and fierce debate, and this has taken on a new dimension as the centuries have passed. Old theories have been challenged and some widely accepted truths are now proven to be myths.

For over 3,000 years the Great Pyramid was the largest human-made structure in the world, but who exactly were the people who built it, toiling for years in the heat and the dust, day in and day out, to create a lasting legacy to the glory and magnificence of their pharaoh? Can we even be sure why it was built? Pyramids have become universally accepted as tombs of the pharaohs. As the final resting place for Pharaoh Khufu, a platform in the air from which he could launch his glorious ascent into the afterlife, the Great Pyramid seems to be no exception. But is there anything that calls this into question, and, if so, what?

Perhaps the biggest spark in the whole debate is not why or who, but how? The scale of such a task by an ancient civilisation with very basic tools is breathtaking. The enormity and complexity of the structure has fired the imaginations of global experts – Egyptologists, scientists, engineers and architects alike – resulting in many differing construction theories as they all strive to unravel the secrets of the most enigmatic structure ever built.

"The enormity and complexity of the structure has fired the imaginations of global experts"

© Getty

MEET THE MAKERS

How work on the great wonder wasn't as slavish as thought

Throughout the decades, thousands upon thousands of schoolchildren have grown up in the belief that the pyramids were built by slaves. In Hollywood epics, we watch as they are forced to drag enormous blocks of stone, their bodies undernourished, their backs lashed by the whips of vicious overseers as they plead for water.

It was a Greek, Herodotus, who first made mention of slave labour during his visit to Egypt in 450 BCE. The thousands of labourers required for such a monument could never, in his eyes, be found through free will. Without any surviving records to tell the true story, it's a notion that has stuck right up to recent times, fuelled by the references to Hebrew slaves in the Book of Exodus. The story of Moses leading the Israelites out of Egypt captured the public's imagination with the help of the golden age of cinema, but has little historical evidence.

The work of modern Egyptologists such as Mark Lehner and Zahi Hawass has turned these popular beliefs on their head and uncovered a much less dramatic, yet much more human face to the builders of the Great Pyramid. Early archaeologists were just as intrigued and enthusiastic as their modern counterparts and established the bedrock for later discoveries. They were on the most part, however, interested in the bigger picture, the awe-inspiring structures that stood before them and the power and majesty of the dynastic pharaohs they represented. The mason and the labourer were of little significance and interest until the end of the Victorian era. But every construction site has its workers, and it's through their lives that the answers to tantalising questions can sometimes be revealed.

Did you know?

The Step Pyramid of Saqqara is the oldest known in Egypt

The discovery of the workers' 'village' at the site of the Giza pyramids in the 2000s opened a window into the ordinary world of men and women as they worked to create something very extraordinary. General everyday items can tell a thousand words, and from this discovery came a new picture. This didn't portray slaves beaten into submission by ruthless tyrants, but honest labourers and skilled craftsmen who

THE PYRAMID CITY

Discoveries have uncovered a large settlement thought to house the skilled labourers of the Great Pyramid

1 THE CEMETERY
Workers and craftsmen who passed away during the construction of the Great Pyramid were buried in places of honour beside the village, often with miniature pyramids of their own.

2 THE WALL OF CROWS
This 200-metre-long ancient stone wall divides the sacred pyramid complex from the workers' village. Experts speculate that it could have served as a symbolic barrier between the land of the dead and the living.

3 TOOLS OF THE TRADE
The Egyptians amassed huge amounts of copper to make the tools needed to construct the pyramids. The fumes from smelting and cooking would have caused an almost permanent haze of smoke to envelope the village.

4 DINNER TIME
Excavations of the workers' village show that as many as 40 cows and sheep were slaughtered each day to feed the hungry labourers. These would have been prepared on-site along with bread and beer.

5 URBAN PLANNING
Unlike the narrow, winding streets usually found in ancient cities, the streets of the workers' village were much broader, allowing more pedestrians access to the dwellings.

DID YOU KNOW? The Great Pyramid has three main rooms

The Great Pyramid is the largest of the three pyramids in the Giza complex

were well nourished, worked hard, were paid for what they did and treated with respect when they died. What has become clear is that for such an undertaking there had to be discipline and organisation on a vast scale, coordinating large cohorts of skilled craftsmen, labourers and support workers in one huge effort towards a single goal.

Burial evidence shows a hierarchy of workers at the site, from temporary seasonal workers to skilled masons, administrators and supervisors, along with their families. There was a daily ration of bread and beer, as well as fish and prime cuts of meat. It's only logical that a well-disciplined workforce needs to be cared for, and an army of builders would definitely march on its stomach. There's also evidence of medical care and on-site doctors who provided aid for a wide list of ailments. These would have been vital in what would have been incredibly long, hard physical labour and all the dangers it would bring.

Evidence of how the workers were organised has also come to light. Estimates as to the entire workforce vary from 10,000 to 20,000 – far fewer than the 100,000 estimated by Herodotus – plus another possible 20,000 temporary or part-time labourers on site for three to four months at a time, all working from 10 to 20 years. But it's how these numbers were used and organised that made such a vast project achievable.

"Men gave their labour instead of taxes"

Workers were broken down into groups of 2,000 and then split again into skilled and unskilled and so on until possibly as few as 20 workers would form a team or 'gang' with a specific task and their own team leader. They also tended to have a particular identity – pyramid graffiti at the third Giza pyramid proudly declares the 'Friends of Menkaure' and the 'Drunkards of Menkaure'.

However, life was not easy on the building site. Another previously unexplored consequence of the construction has emerged – the unification of Egypt as a nation. Although they weren't slaves forced into hard labour, as is common misconception, in some ways the builders did not give their time freely.

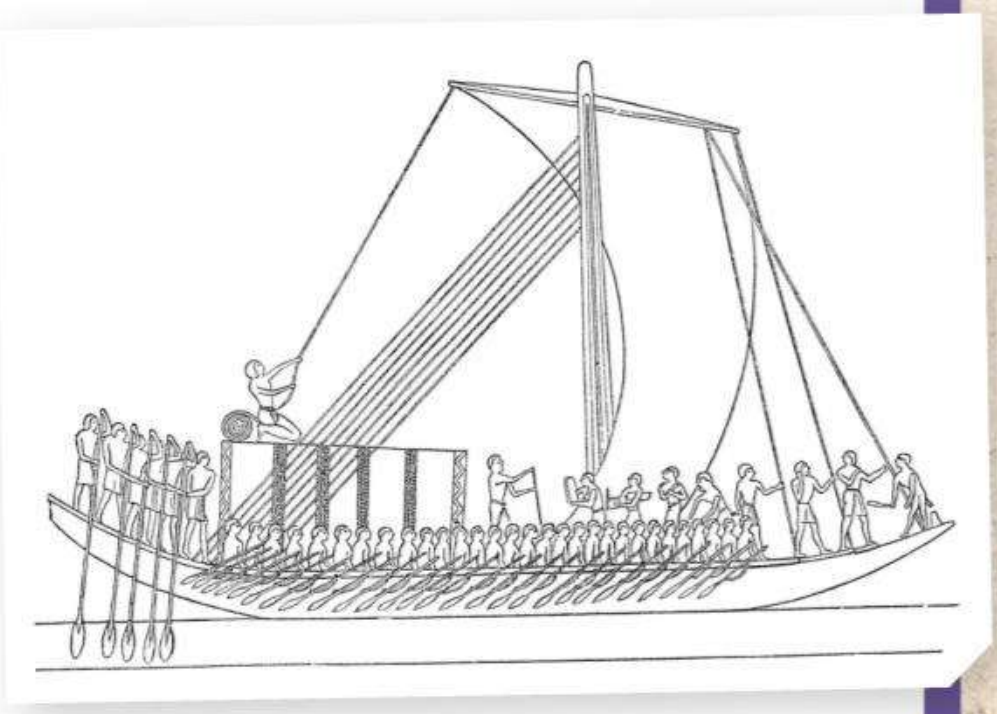
Records of local leaders show that there was an obligation to the pharaoh to supply men for such projects in much the same way as feudal kings relied on their nobles to supply men-at-arms in times of war. There is also a possibility that men gave their labour instead of taxes. DNA testing on the remains of workers from the Giza village clearly demonstrates that the workforce came from all over Egypt, fulfilling an obligation and answering their pharaoh's call as homage to their god-king.

As a result, men and women from all parts of the kingdom came together, shared their lives, learned new skills, made new friends and returned home with a greater sense of unity, having been part of a lasting legacy to their all-powerful ruler.

BLOCKS ON BOATS

While the workers may have lived next to the construction site, how did they transport the building materials? Experts have traced the granite used in the Great Pyramid's inner chamber to quarries in Aswan, which lies 533 miles south of Giza. Meanwhile, the monument's outer casing required 170,000 tonnes of limestone. New archaeological evidence suggests that they transformed the landscape, creating a purpose-built canal system to transport it all.

A papyrus scroll found at the seaport Wadi Al-Jarf offers a firsthand account. Written by Merer, an overseer in charge of a team of 40 elite workmen, the scroll explains how they transported two-tonne limestone blocks eight miles downstream from a quarry at Tura to Giza. The blocks were balanced on wooden boats, held together by rope. The overseer also describes how his crew opened giant dykes to divert water from the Nile and channel it to the pyramid through human-made waterworks. To corroborate the ancient record, Mark Lehner, the American archeologist who helped find the workers' village, believes he has mapped the lost waterways beneath the dusty Giza plateau.



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A RIDDLE IN THE SANDS

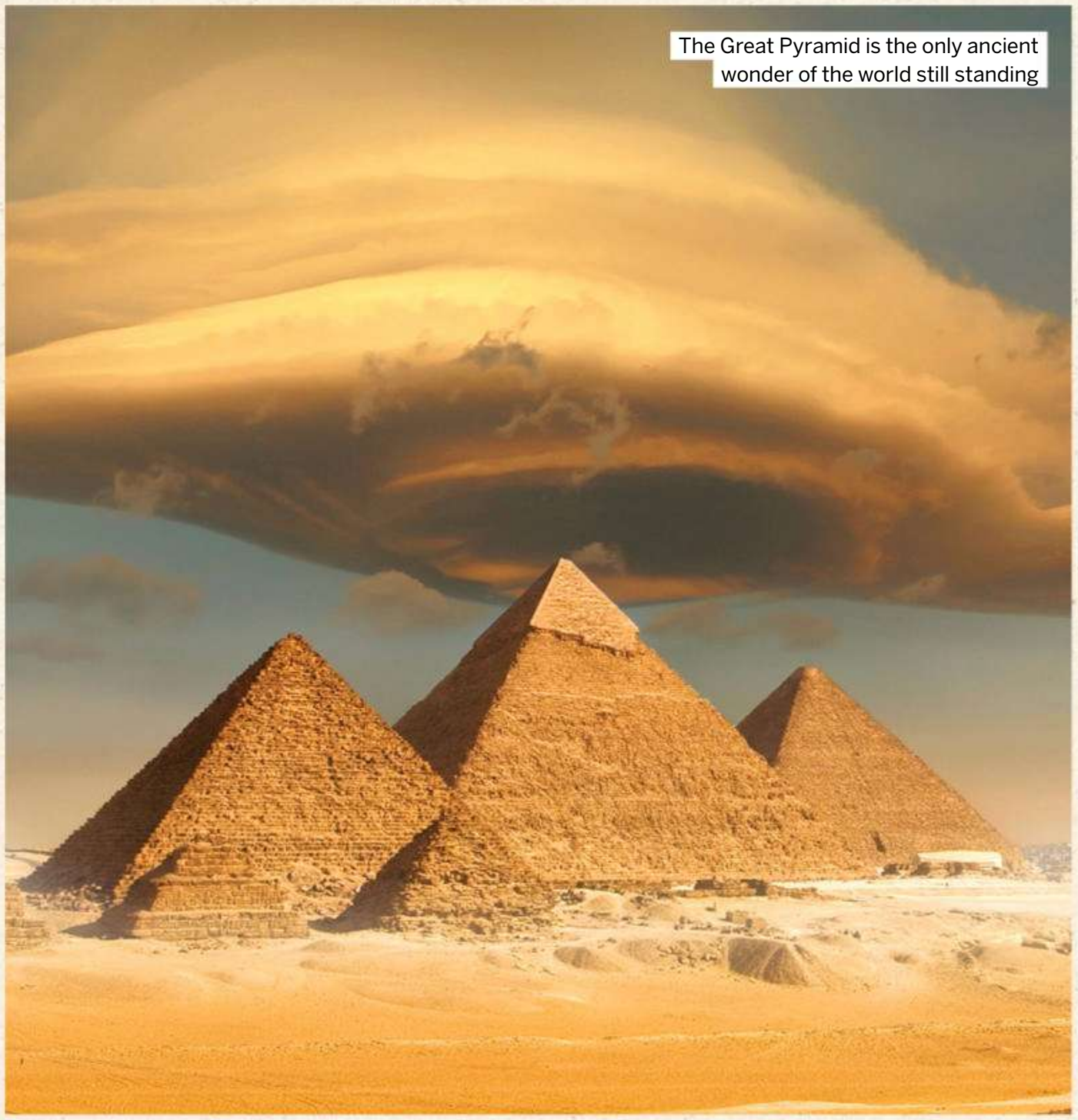
Piecing together a giant jigsaw puzzle has revealed Giza's secrets

To match the organisational discipline of the workforce, there had to be skill and precision in the planning and calculations required for such a tremendous project. Many of the questions still debated today revolve around the details of construction. While there is some accepted common ground, differences still remain. For those trying to solve the mystery, it has been essential to place themselves in the minds of those ancient designers and architects and ask some very fundamental questions, such as what are we trying to achieve and what knowledge do we have to achieve it?

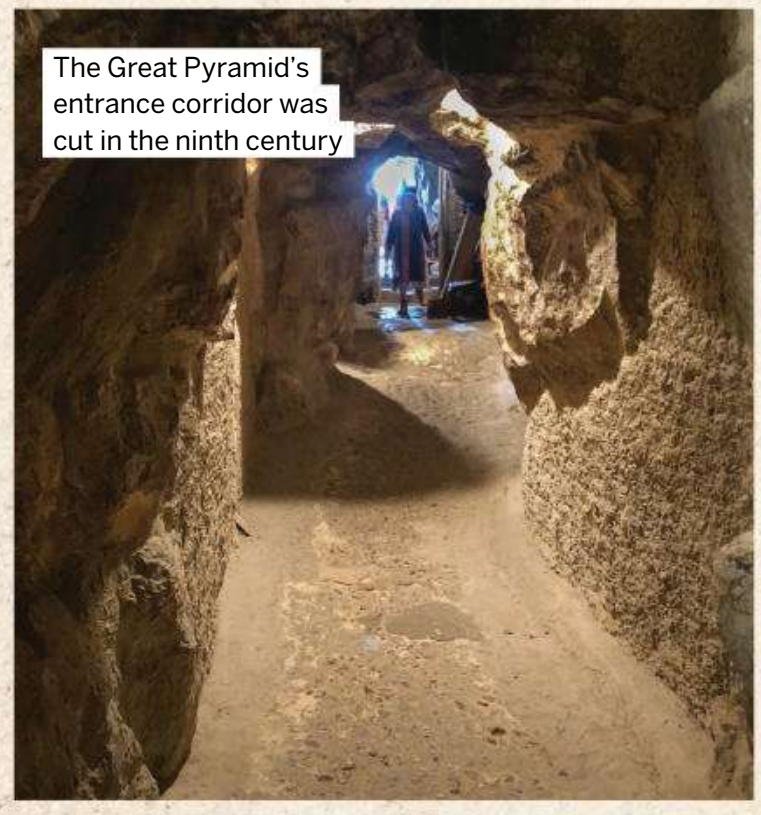
We know that at the time of the construction of the Great Pyramid, the Egyptians didn't have the wheel. Nor did they have pulleys or iron tools. What they did have, however, was the knowledge and instruments to measure level surfaces and angles, both essential for precision on an amazing scale, even by modern standards. As for tools, they had the know-how to use sand and other abrasives to turn a copper saw into a much more efficient instrument that could cut through relatively soft limestone, and even the larger granite blocks with surprising success.

The debate around the construction of the Pyramid of Khufu falls quite neatly into some very simple questions. How did they move such large blocks? Without the wheel, it's generally accepted that they were able to construct sleds on which the stone blocks could be pulled while

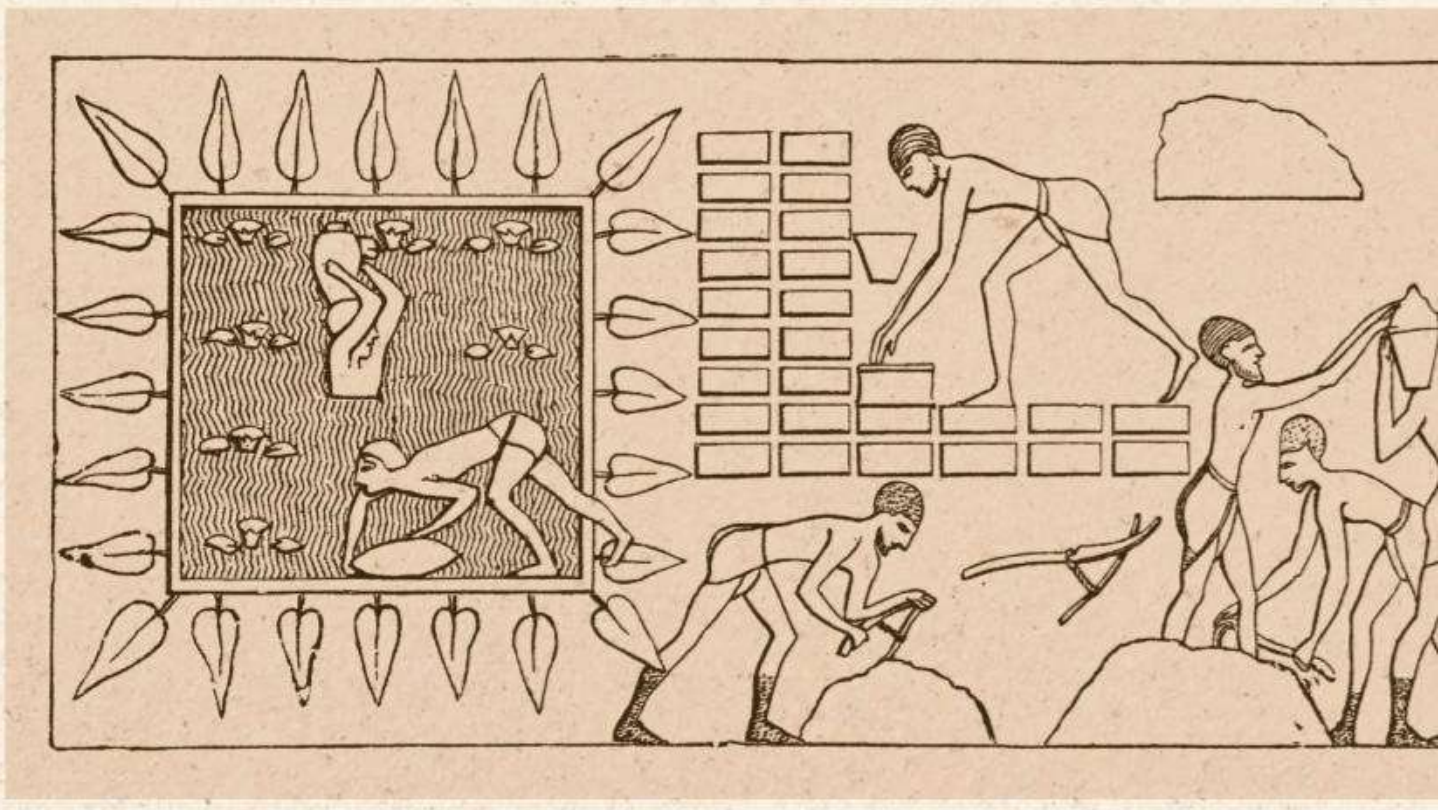
"How did they move such large blocks?"



The Great Pyramid is the only ancient wonder of the world still standing



The Great Pyramid's entrance corridor was cut in the ninth century

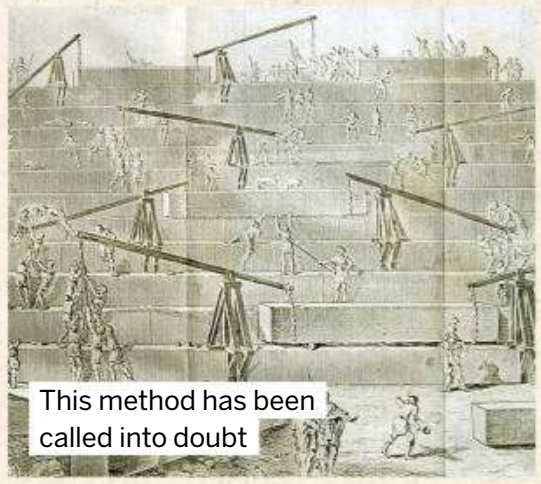


THE BIG BUILD THEORIES

Alternative construction methods are a hot topic among Egyptologists

STEPS AND LEVERS

If the writings of Herodotus are to be believed, the construction of the pyramids was based upon a step-by-step method or, in his words, 'stairs'. Once the foundation of the structure had been established, each successive layer was put in place, each set a little back from the edge to create a ledge on which workers could use levers to move the stone up to the next level. Once the top was reached, the outer layer of brilliant-white limestone was put in place in descending order to make a smooth outer surface. However, the sheer angle at which the blocks would have to be levered and the time it would take makes this method less plausible.



This method has been called into doubt

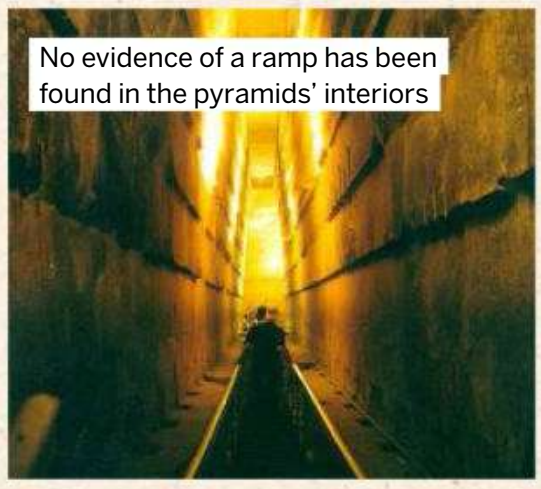
CONCRETE BLOCKS

Scientist Joseph Davidovits claims that the majority of the blocks used in the Great Pyramid were not quarried at all but were moulded into shape using a kind of limestone concrete that would then set and look like a limestone block. This would reduce any transportation of heavy blocks as they would be created on site and the moulds reused. However, his hypothesis is not accepted by mainstream Egyptologists. Given the chance, workers would certainly have made their own lives easier by creating straight edges, but most of the blocks are irregular in shape and size. They also show marks of chiselling and masonry working.

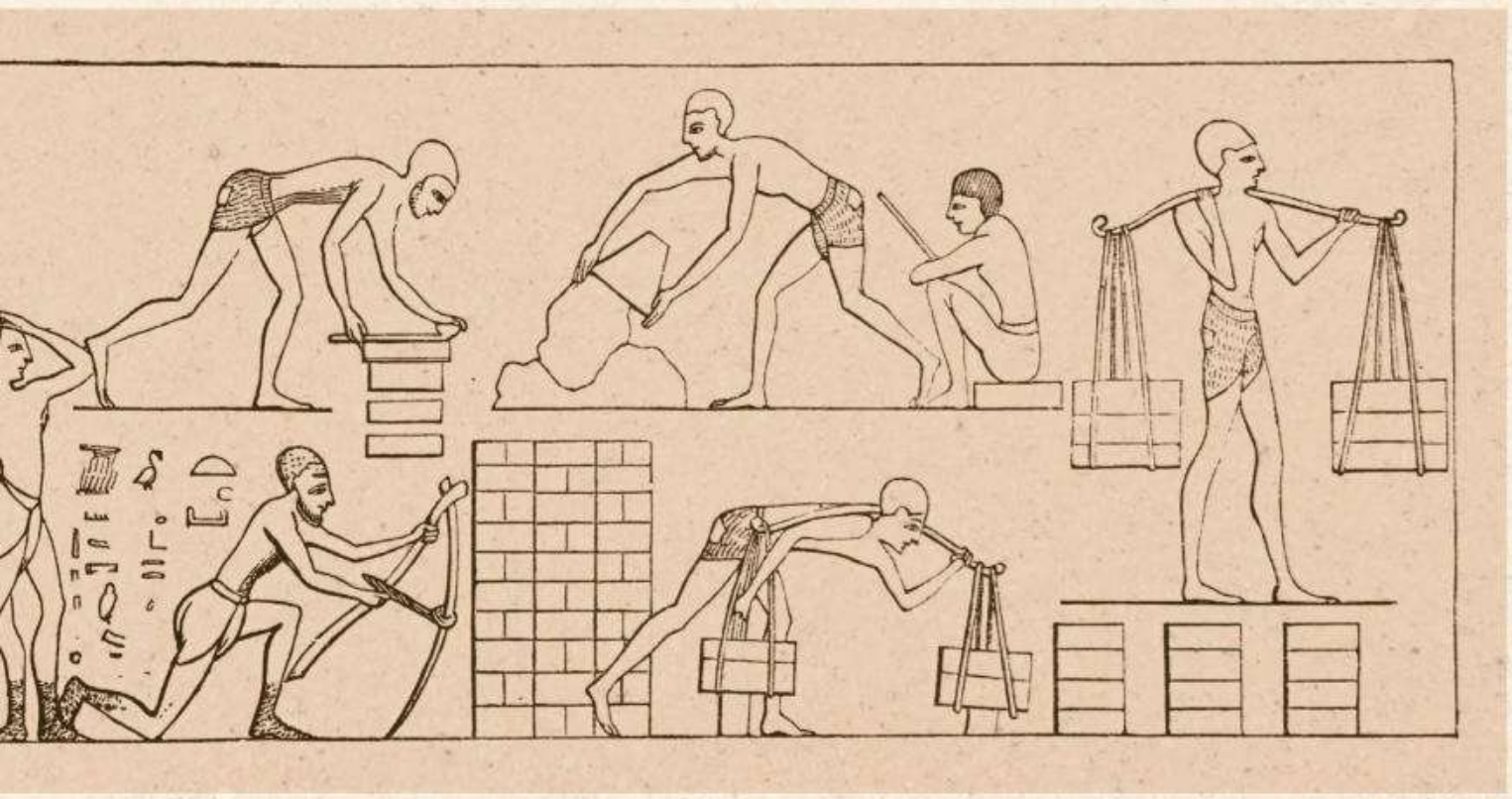
The blocks are too irregular to have come from a uniform mold

INTERNAL RAMP

French architect Jean-Pierre Houdin has a hypothesis that the ramp used was internal. In much the same way as the spiral ramp, at an angle of seven degrees, Houdin claims the external blocks were put in place first to ensure the precision of the smooth-angled finish of the pyramid, with the ramp running around the structure inside the outer wall, allowing builders to work on construction either side. Gaps on each of the corners would allow blocks to be turned at right angles and carry on up the ramp. No internal ramp has been found, though an unusual, unexplained gap in one corner of the pyramid has yet to be explored.



No evidence of a ramp has been found in the pyramids' interiors



the ground was lubricated with water to reduce friction. Such a sled is displayed in excellent condition in the Museum of Cairo, and there are examples of tomb decoration showing statues being pulled into place on one. Timber was a rare commodity in Egypt, with much of it coming from Lebanon, and so the sleds would be well maintained and would be recycled into perhaps roof beams or even beds or furniture when they were no longer needed.

Perhaps the most controversial question of all is just how the huge blocks of limestone, and later the even bigger blocks of granite, were manoeuvred into place with such breathtaking precision, with joints of only half a millimetre, onto a monument as it rose higher and higher from the ground. The essential starting point for construction was a level base. In the 1880s, Sir Flinders Petrie surveyed the site and concluded that the area had been dug with shallow channels and flooded so that the water established the true level and the stone worked into a flat surface between. This idea was developed by Lehner 100 years later, with the hypothesis that only an area suitable for sufficient foundation was levelled. Whichever method was used, the base of the pyramid is flat to within an astonishing 15 millimetres.

Many experts agree that in order to get such huge blocks of stone into place, they must have used a ramp. The burning question is what kind? It's now widely understood that a straight one at right angles to the structure is the least likely answer to the mystery. The main reason for this is the sheer size of the structure required – almost as bulky as the pyramid itself – and the steepness of the angle required to reach the higher points, which would be beyond the capabilities of a sled drawn by humans.

Perhaps more promising is the zig-zag ramp, which would snake up one side of the structure with shorter lengths at a less steep angle. The main issue would be keeping it fixed to the exterior of the structure as it grew. By introducing a spiralling ramp, supported by the body of the structure itself, the architects would overcome a number of logistical obstacles.

First of all, the angle would be shallow enough for the effective pulling of the blocks. Second, it would not have to be fixed to the angled outer surface of the pyramid but would rise on top of each layer as it progressed in height. Third, the final top section of the pyramid would be put in place using levers in very much the way as described by Herodotus. In order to then fix the finely finished outer layer, the whole process would be done in reverse and the ramp dismantled as they went.

Perhaps the most frustrating aspect of the pyramids' construction is the lack of any records revealing the construction techniques used on them. But the more recent work that has been undertaken moves us evermore forward in our knowledge and to resolving the mystery once and for all.

© Alamy / Getty

A GOD-KING'S SECRET

Uncovering Khufu's final resting place

The completed pyramid and last resting place of Pharaoh Khufu is in many ways very different from other examples of the structures as burial chambers and has led to speculation as to its actual use. Thousands of years of looting and grave robbing have deprived us of studying the mummy and grave goods that would have been placed within, limiting our knowledge of what the individual chambers were used for.

The only intact image we have of Khufu is a small statue in the Cairo Museum

1 KING'S BURIAL CHAMBER

This chamber houses the single sarcophagus of the pharaoh, which is slightly larger than the ascending passage and must have been in place before the roof was finished. The chamber is almost entirely constructed of heavy granite blocks, some of which are 80 to 100 tonnes. Above the chamber are the stress-relieving blocks. These are an ingenious system of granite blocks, laid in such a way as to create separate chambers to take the enormous weight of the pyramid above it and distribute it away from the ceiling of the King's Chamber, thus preventing collapse. Two shafts align with certain stars and were also at first thought to have been for ventilation, calling into question the original purpose of the pyramid. However, it's now widely accepted that they act as a symbolic link with the afterlife.

2 THE GRAND GALLERY

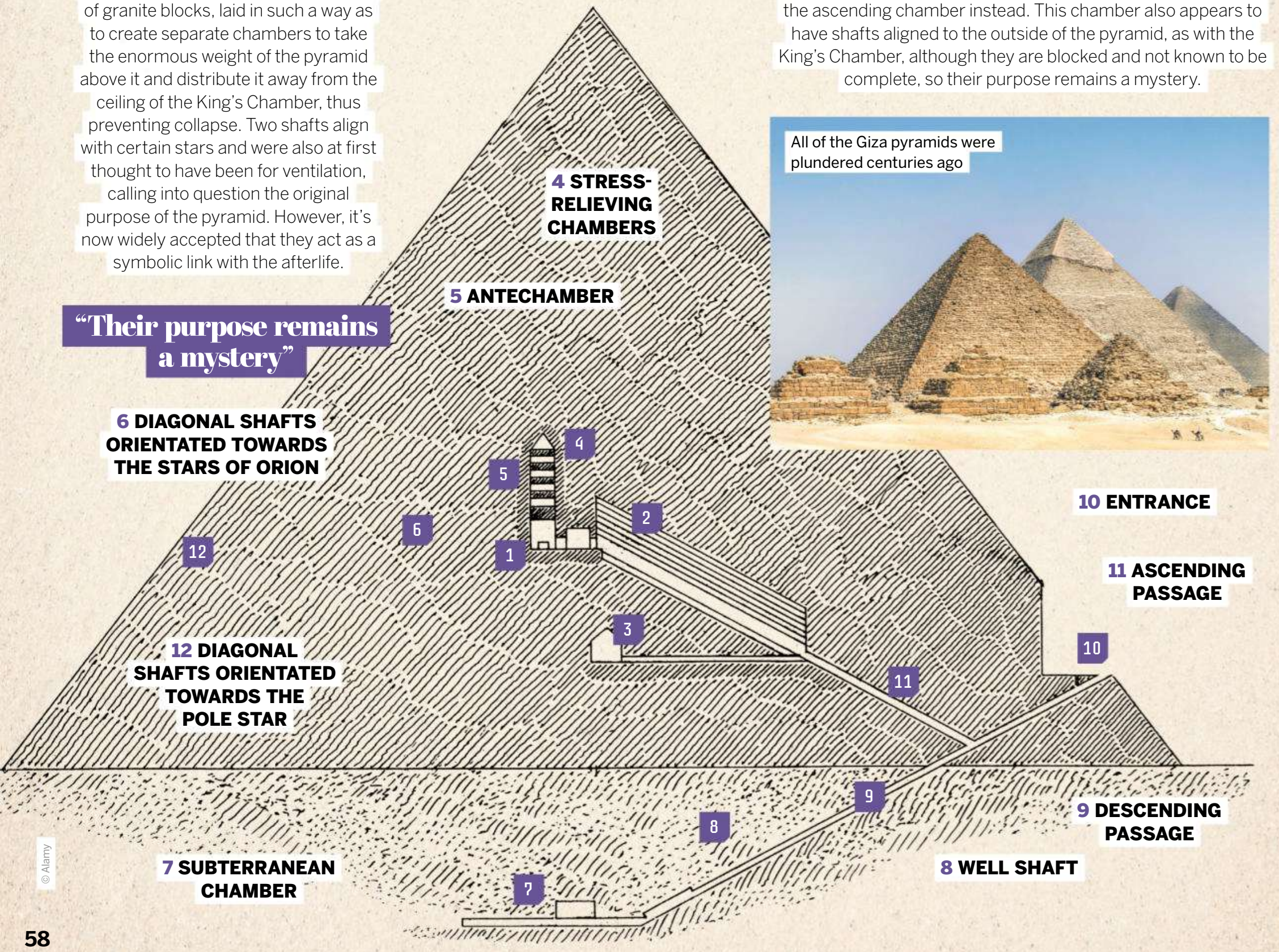
This gallery is 8.6 metres high and 46.7 metres long and links the king's burial chamber to the rest of the interior. It would originally have been sealed off by a series of doors, thereby cutting the burial chamber off completely from the outside world. Another hypothesis raised by Jean-Pierre Houdin is that the gallery was constructed as part of a kind of 'escalator' system to raise the granite blocks to the chamber.

3 QUEEN'S CHAMBER

Measuring 5.75 by 5.23 metres, this chamber is aligned exactly halfway between the north and south sides of the pyramid. The original purpose of this chamber remains unsolved. As there are other smaller pyramids on the Giza site attributed to Khufu's wives, it has been speculated that it was the original resting place for Khufu, descending into the pyramid in a more traditional manner, but that he changed his mind and opted for the ascending chamber instead. This chamber also appears to have shafts aligned to the outside of the pyramid, as with the King's Chamber, although they are blocked and not known to be complete, so their purpose remains a mystery.

All of the Giza pyramids were plundered centuries ago

"Their purpose remains a mystery"



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FUTURE

INSIDE THE PENTAGON

Explore the US Department of Defense's headquarters and discover the many high-security areas this iconic building houses

WORDS **AILSA HARVEY**

In Virginia, near Washington DC, the headquarters of all the United States' military defence departments combine to form a super-secure and highly surveilled base. The pentagon-shaped building covers an area of over 500,000 square metres, where 30,000 people work to keep the country safe. Built to withstand almost any attack, the concrete-and-steel structure contains five pentagon-shaped rings within one another and has a total of seven floors, both above and below ground.

The Army, Navy and Air Force are all based in this substantial building, which was built between 1941 and 1943. Prior to its construction, the offices for the US military departments were spread across 17 different locations. With their expansion during World War II, President Franklin Roosevelt ordered the construction of the Pentagon to bring all of these departments under one roof.

Tasked with this immense project, lead architect George Edwin Bergstrom needed to ensure neither space nor safety were compromised in his design. Because of the surrounding roads at the original site and a requirement to limit the building's height so as not to block views of Washington, Bergstrom planned the construction of an irregularly shaped five-sided ring. The site was later moved 0.75 miles further south so there was room to make the building symmetrical. Even though the new area had fewer roads to restrict the space, the unique shape was kept so that the Pentagon could be built quickly.

Did you know?

The Pentagon has six different postal codes

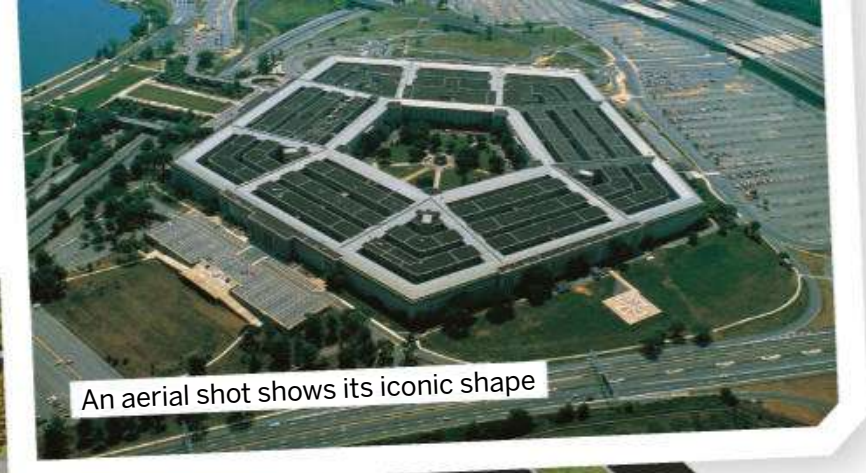
5 CAFETERIAS
In the Pentagon's cafeterias, everything from fast food to fine dining is available.
4 ARMY SIGNAL CORPS AUDITORIUM
All of the army's systems of communications are managed here.
2 MILITARY DISPENSARY
The military's medical supplies are stored and dispensed here.
6 SENIOR OFFICERS DINING ROOM
Senior members of staff are offered a more exclusive dining experience.
7 AIR FORCE MISSILE OFFICE
Missile production, use and storage is controlled here.
8 LARGE CONCOURSE
In this large open area there are shops, banks and post offices.
9 NATO OFFICES
Employees working in these offices communicate and work with the 29 other North Atlantic Treaty Organization countries.
2
4
6
7
8
9

DEADLY ATTACK

Following the attacks on the Twin Towers in 2001, American Airlines Flight 77 struck the Pentagon. On the southwestern side of the building, the outside ring was hit first, but the plane continued to plough through the next two inner rings of offices before coming to a stop. This happened exactly 60 years after the Pentagon's construction began. After the impact, the crash produced a large fire that continued to burn for 36 hours. Tragically, a total of 125 employees at the Pentagon lost their lives. The Phoenix Project was launched to repair this part of the Pentagon. By the time it was completed in February 2003, about $5 billion was spent on the reconstruction and renovation.

There's a Pentagon 9/11 memorial site to remember those who were lost in the terrorist attack

DID YOU KNOW? There are almost 18 miles of corridors making up the Pentagon



An aerial shot shows its iconic shape

BEHIND THE WALLS

What goes on inside the Pentagon's five sides and across its many floors?

1 AIR FORCE AREA
This is the site of the main research and operation planning by the US Air Force.

3 ARMY AREA
This section houses the military government and legal offices.

11 NAVY AREA
In these offices, research into current weather and warfare is carried out by navy officers.

12 POLICE HEADQUARTERS
As one of the US' most guarded buildings, there's a high police presence.

15 HELICOPTER LANDING AREA
Military leaders and VIPs from other countries are flown to and from the Pentagon's heliport.

10 ARMY COMPUTERS
Some of the most important data is stored safely underground.

13 CENTRAL CAFE
At the centre of the Pentagon's five-acre park is a cafe.

14 UNDERGROUND FILES
Top-secret army files are locked away in the basement under the Pentagon.

© Getty / Illustartion by Nicholas Forder

WORDS **LAURA MEARS**

HUNTING HURRICANES

What are hurricanes and how can we tell when they're coming?

DID YOU KNOW? Hurricanes can spawn tornadoes when they make landfall because the wet air they carry collides with dry air

Hurricanes are some of the strongest and most dangerous weather events on the planet. Between 2000 and 2020, they claimed the lives of 2,137 people in the US alone. These rotating thunderstorms are relentless, taking days to pick a path through towns and cities before burning out. Each one can measure 300 miles from end to end and stretch 9.5 miles into the sky. And they all have winds in excess of 74 miles per hour – the Labour Day hurricane of 1935 topped out at 185 miles per hour.

The ability to predict these storms has changed the world. People in hurricane-prone areas now receive warnings days before deadly winds arrive. But it's not an exact science. Hurricanes are chaotic in the true mathematical sense of the word; one tiny change can cause a dramatic difference in their behaviour. It's up to organisations like the National Oceanic and Atmospheric Administration (NOAA) to plot the path each tropical storm will take and make sure everyone has time to get to safety.

Hurricanes are not the only type of spinning weather system. They belong to a group of storms called tropical cyclones. The word 'hurricane' describes the strongest of the cyclones in the North Atlantic, central North Pacific and eastern North Pacific Oceans. In the Northwest Pacific, the same strong weather systems are called typhoons, and in the South Pacific and Indian Ocean they are all known as 'tropical cyclones', regardless of their strength. Tornadoes are a different type of weather entirely. They are much smaller than hurricanes and form over land, not water. They tend to last just a few minutes and don't travel nearly as far.

A hurricane is different to a waterspout, which is a tornado that forms over water

GREAT GALVESTON HURRICANE

On 8 September 1900, the biggest city in Texas was flattened by a hurricane. Forecasters had warned of a tropical storm south of Florida two days earlier, but they thought it was moving northward. Unknown to them, it was actually turning west into the Gulf of Mexico and rapidly growing in strength. Ships had noticed the disturbance, but had found it hard to get messages back to shore. The weather was worsening, and the tide was rising, but by the time the local weather bureau started warning people to leave, it was already too late. Winds had picked up to 140 miles per hour and waves were towering 4.5 metres into the air. It wasn't the strongest hurricane ever to hit the US, but was by far the deadliest. It claimed the lives of around 8,000 people.

This pressure map shows the Galveston hurricane just before it came ashore

© Getty / Wiki: Julian Kupfer / NOAA

It's not uncommon for storms to stack up back to back during hurricane season

ANATOMY OF A HURRICANE

As hot air rises from the oceans near the equator, a storm can start to spin

1 AIR RUSHES IN
High-pressure air moves through the eye of the storm.

2 EYE OF THE STORM
The centre of the storm is still and calm while air rotates around the outside.

3 THE EYEWALL
A fast-moving wall of cloud surrounds the eye of the storm.

4 HOT AIR RISING
Air rises from the surface of the sea, leaving empty space behind.

5 WARM WATER
Hurricanes feed on the warm, damp air that evaporates from tropical oceans.

8 SPIN
Air curves over the Earth's surface as it moves through the storm, setting the whole system into a spin.

THE MAKING OF A HURRICANE

You need four ingredients to cook up a perfect storm: warm water, wet air, slow winds high in the atmosphere and a cluster of thunderclouds waiting to become something bigger. Hurricanes often start out as small storms off the coast of Africa. Known as 'tropical depressions', these embryonic cyclones move west, picking up strength as they cross the Atlantic. They can only grow when the temperature of the water exceeds 27 degrees Celsius, and this is only at certain times of year. In the Atlantic, hurricane season runs from 1 June to 30 November. In the eastern Pacific it starts about two weeks earlier.

When the water is warm, it starts to evaporate, making the air wet. The vapour rises into the atmosphere, and if the wind is calm it condenses to form clouds. If the air moves too quickly, the top of the developing storm simply blows away. But if the conditions are right it starts to draw more air upwards, just like a plug hole drawing water from a bath. Just like a plug hole, the air entering the storm starts to spin.

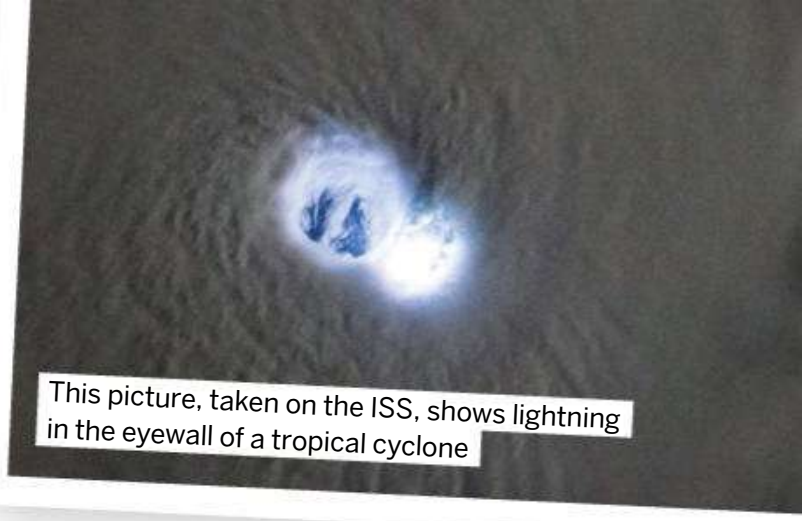
The spin of a hurricane is down to the Coriolis effect. Earth, as everyone knows, is a spinning ball. Every point on its surface takes 24 hours to complete one rotation. This means that the points on the equator move much faster than the points on each of the poles. And this means that winds travelling over Earth's surface don't go in a straight line. In the Northern Hemisphere they bend off to the right, and in the Southern Hemisphere they bend left. That's why hurricanes always spin in the same direction.

Did you know?
Hurricanes never form directly over the equator

But just because the winds twist in a predictable way doesn't mean that the storms

DID YOU KNOW? The largest storm ever recorded on Earth was Typhoon Tip in 1979

7 THUNDERCLOUDS
The evaporated water in the rising air condenses to form thick clouds.
7
6 LOW PRESSURE
The gap left by the rising air sucks more air into the storm.
6



This picture, taken on the ISS, shows lightning in the eyewall of a tropical cyclone

EVOLUTION OF HURRICANE IAN

Hurricane Ian battered Cuba and the East Coast of the US in September 2022

1 TROPICAL STORM
Hurricane Ian started as a tropical disturbance in the Atlantic Ocean before moving west into the Caribbean Sea.

2 CATEGORY 1 HURRICANE
The storm moved north over Cuba, becoming a category 1, 2 and then 3, with wind speeds over 100 miles per hour.

3 CATEGORY 4 HURRICANE
By the time Ian made landfall in Florida, it was a category 4 hurricane with wind speeds in excess of 150 miles per hour.

4 CATEGORY 1 HURRICANE
As the storm moved north towards Charleston, it weakened first to a category 1 and then a tropical storm.

NATURAL WARNING SIGNS

THE SEA SWELLS
As a hurricane approaches, the sea starts to get rougher. This can happen days before landfall. Waves rise, lifting to heights of two metres or more.

THE CLOUDS CHANGE SHAPE
Hot air rising from the sea carries water into the sky, forming distinctive clouds. Cirrocumulus clouds look like ripples.

ANIMALS HIDE
Many animals sense changes in air pressure before a storm. In the sea, sharks, dolphins and lobsters move to deeper water.

themselves are easy to forecast. Of the hundreds of storms that roll towards the US each year, only around 29 gather enough strength to get names, 15 reach wind speeds high enough to become hurricanes and just seven become major hurricanes.

It's the job of the National Hurricane Center (NHC) to keep track of them all and to work out when to sound the alarm. A team called the Hurricane Specialist Unit keeps a constant watch over the Atlantic and the Eastern North Pacific oceans. Satellites orbit the world from top to tail twice every day, taking pictures, measuring the temperature and tracking the amount of moisture in the air. If anything looks suspicious, the NHC sends in the hurricane hunters, This elite team of planes and pilots specialise in chasing storms. They fly right into the wind, gathering measurements as they go. It might sound dangerous, but the risk of damage to the aircraft is low. Meteorologists use the data from these flights, the satellites and other weather instruments to predict what a storm might do next. It's not an exact science, so the NHC repeats the process every few hours, adjusting its forecasts as each storm evolves.

© Getty / NOAA / International Space Station Expedition 42 crew / NASA Earth Observatory image by Jesse Allen, using VIIRS data from the Suomi National Polar-orbiting Partnership

ARE HURRICANES GETTING STRONGER?

As Earth's climate changes, extreme weather is too

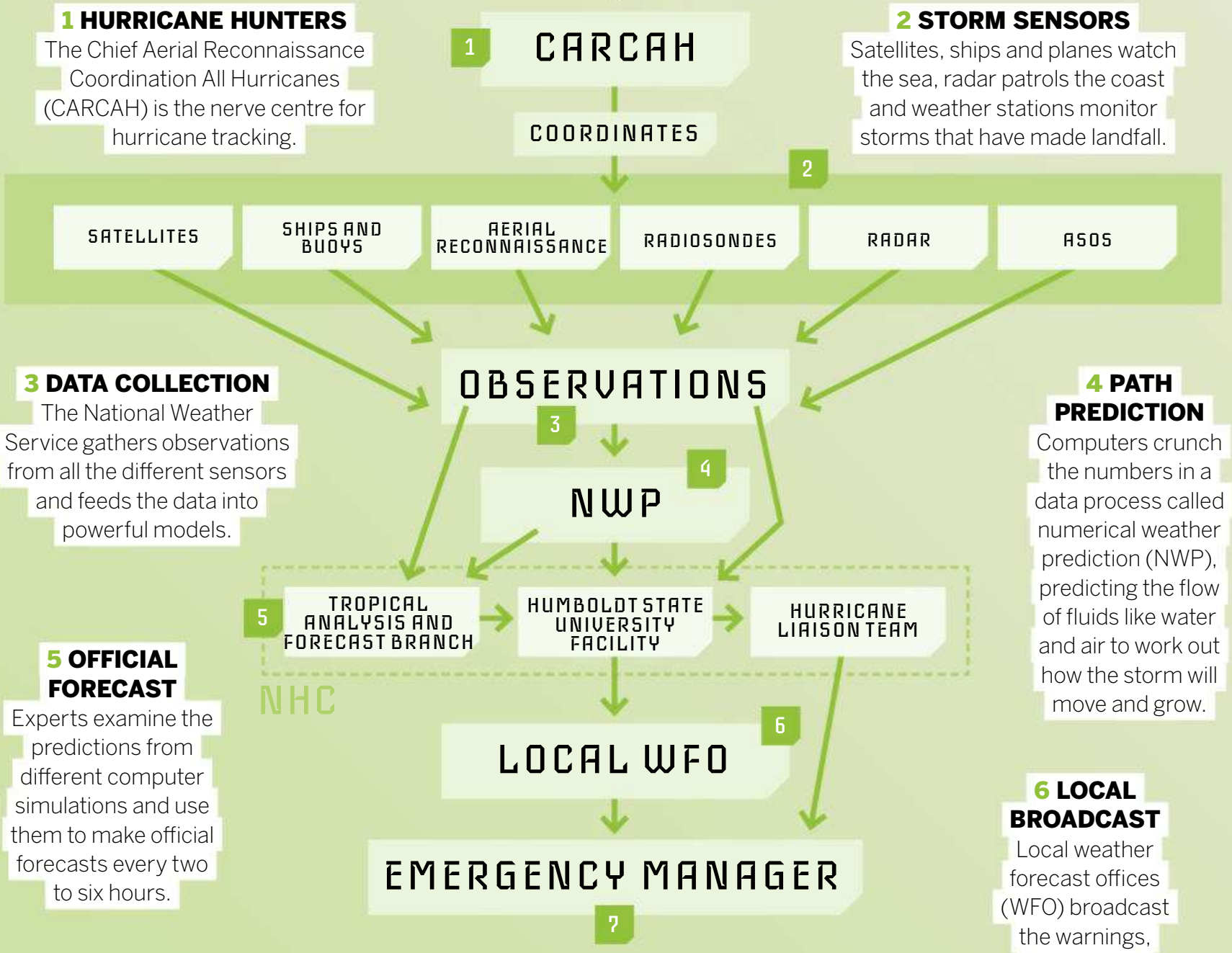
There's no doubt that our climate is changing – NASA says the evidence is unequivocal. Current warming is happening faster than at any other time in the past 10,000 years. But the effect a warmer world will have on hurricanes is hard to predict. Rising global temperatures are likely to impact hurricanes because tropical cyclones feed on warm, wet air. But the complex nature of these storms makes it impossible to know exactly how they'll change over time. On average, the evidence suggests that hurricanes are likely to become more frequent and more dangerous. As the world gets warmer, the air will get wetter, and wetter air means heavier rain. It's chemistry: the hotter it is, the more evaporation there will be. Storm-induced flooding will also be more likely as ice sheets melt and the sea expands.

PREDICTING HURRICANES

How does the National Hurricane Center keep track of incoming storms?

1 HURRICANE HUNTERS
The Chief Aerial Reconnaissance Coordination All Hurricanes (CARCAH) is the nerve centre for hurricane tracking.

2 STORM SENSORS
Satellites, ships and planes watch the sea, radar patrols the coast and weather stations monitor storms that have made landfall.



3 DATA COLLECTION
The National Weather Service gathers observations from all the different sensors and feeds the data into powerful models.

4 PATH PREDICTION
Computers crunch the numbers in a data process called numerical weather prediction (NWP), predicting the flow of fluids like water and air to work out how the storm will move and grow.

5 OFFICIAL FORECAST
Experts examine the predictions from different computer simulations and use them to make official forecasts every two to six hours.

6 LOCAL BROADCAST
Local weather forecast offices (WFO) broadcast the warnings, making sure residents have the most up-to-date information for their area.

7 EMERGENCY RESPONSE
Emergency managers coordinate with local weather offices and the National Hurricane Center to decide if and when to evacuate.

5 FACTS WEATHERING THE STORM

1 STOCK UP
It's recommended to stock up on emergency supplies in advance of the hurricane season. The list includes food, water, medicine, torches, batteries, important documents and a fire extinguisher.

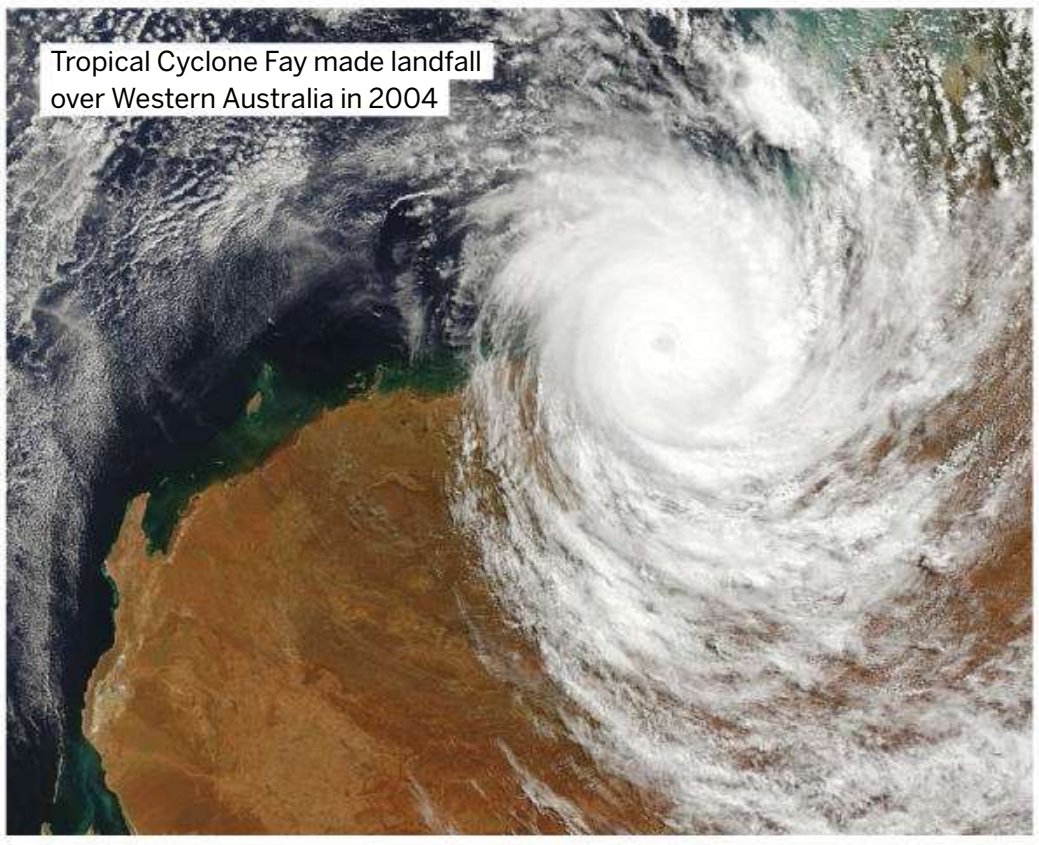
2 WIND-PROOF YOUR HOME
The Red Cross Hurricane Safety Checklist suggests protecting homes by removing or anchoring loose objects in the garden, covering the windows with storm shutters and trimming nearby trees.

3 STAY INFORMED
The Federal Emergency Management Agency recommends signing up to local alerts. The National Weather Service gives each storm a warning level: yellow advisory, amber watch and red warning.

4 TAKE AN INVENTORY
The Insurance Information Institute suggests taking an inventory before hurricane season. This makes it easier to claim disaster aid or an insurance payout if anything is damaged.

5 MAKE A PLAN
NOAA suggests making an emergency plan with friends and family. It helps decide in advance where to go, what to take and how to get there.

DID YOU KNOW? The most expensive hurricane was Katrina in 2005 – it caused damage totalling $180 billion


Tropical Cyclone Fay made landfall over Western Australia in 2004

Hurricane Sandy flooded the New York subway system in 2015

Did you know?

Wetter air means heavier rain. Higher sea levels mean more flooding

Floodwater from downgraded tropical storm Irene carried houses away in Vermont in 2011

INTERVIEW WITH A HURRICANE SCIENTIST

Dr Jordan J. Gerth, a physical scientist at the National Oceanic and Atmospheric Administration (NOAA), talks to us about using satellites for hurricane forecasting

How much has satellite technology changed hurricane forecasting?
It's hard to imagine hurricane forecasting without the use of satellites. Satellites are a primary tool to track storms and monitor their intensity over the ocean. Without them our only indication would be buoys and ships, and there would still be a substantial number of storms that would be a surprise upon landfall, of great consequence to the people that live along the coasts.

How much does NOAA rely on satellite data?
Satellites are fundamental to NOAA's mission and our ability to predict the weather. NOAA runs sophisticated computer models that use satellite data as a primary input for weather conditions around the world. Satellites provide over 90 per cent of the input to these. Without fully knowing global weather conditions, it's difficult to make local predictions and warnings.

Are there ever times when satellites are suggesting one thing, but experience and instincts suggest otherwise?
Satellites provide critical observations and meteorologists are trained to not look beyond the data. However, sometimes despite all of our advances in weather prediction, internal storm dynamics are difficult to immediately ascertain with the data that's available. In those cases, the National Weather Service has to rely on rigorous training, expertise of colleagues and computer simulations to provide the best forecast.

Are there still technological advances on the horizon that could improve hurricane forecasting even further?
Yes! NOAA established the Hurricane Forecast Improvement Program (HFIP) after devastating hurricanes in 2004 and 2005, such as Katrina, to improve the accuracy, and therefore Americans' confidence, in hurricane forecasts. Recently, HFIP is leading to the development of a Hurricane Analysis and Forecast System to improve hurricane forecasts with advancements in computer models. NOAA is also planning future satellite missions that include enhanced capabilities for monitoring hurricanes and funding research projects to collect additional data with hurricane hunter aircraft.

Will it get easier or harder to predict hurricanes as the climate changes?
Climate change is unlikely to change the predictability of hurricanes, but it may lead to stronger hurricanes. Hurricanes typically increase in intensity under low wind shear around the storm and warm water temperatures. Under a changing climate, there's evidence that water temperatures will be on the increase.

© NASA / U. S. Fish and Wildlife Service - Northeast Region / Metropolitan Transportation Authority of the State of New York / American Meteorological Society

HOW ICEBERGS FORM

Discover the life cycles of these giant chilly chunks of glacial debris

WORDS AILSA HARVEY

In Earth's polar regions, large sheets of ice cover extensive areas of land, such as in Antarctica, where 97.7 per cent of its surface area is covered by permanent ice. These icy landscapes might appear completely stationary, but they are actually made of slowly moving glaciers. Because these landscapes are tightly packed with snow, which over time creates dense ice, some of the largest glaciers can weigh 10 million tonnes. When this ice creeps into the polar seas, small segments of this glacial ice eventually break under the force of gravity. This results in around 40,000 irregularly shaped and unique blocks of ice floating on the surface of our seas, called icebergs.

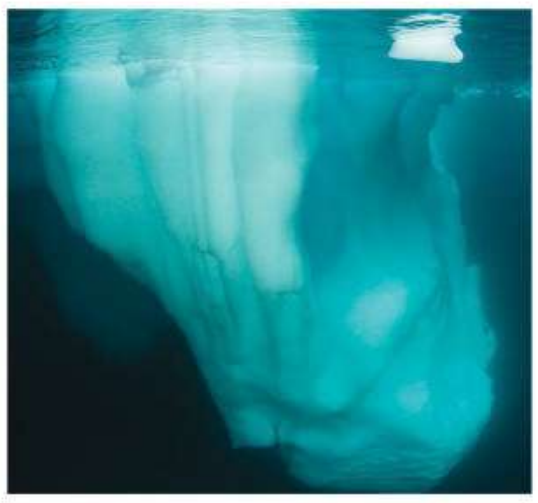
Icebergs are blocks of ice covering an area of at least 500 square metres. What makes them stand out is that they have been in the making for thousands of years. As more and more snow falls onto glacial ice, the increasing pressure from above squeezes out much of the trapped air, giving the ice below a rigid crystal structure.

Once an iceberg calves, or breaks loose from a glacier, it follows the motion of the ocean, melting slowly over the course of around three to six years. Some icebergs disappear prematurely, either because they move into warmer equatorial waters or because they collide with other icebergs and break apart.

DID YOU KNOW? The largest recorded iceberg, B-15, was calved in 2000 and measured 159 by 20 miles

TIP OF THE ICEBERG

From above the water, some icebergs appear huge, but this is just a small part of them. About 90 per cent of the ice floats below the waterline. With only one-tenth of the iceberg's mass above the surface, it might seem surprising that these frozen blocks don't sink. This works because of the density difference between freshwater and saltwater. Seawater is more dense than the iceberg, so the ice rises to the surface. The hydrogen bonds of the ice are spaced farther apart than the molecules in water, so the mass of the iceberg will take up much more space than the equivalent mass of water. Icebergs are also filled with trapped air, adding buoyancy and whiteness.



Underneath an iceberg off the east coast of Greenland

AI AVOIDANCE

Many people are aware of the tragic story of the Titanic, the 269-metre-long passenger liner that fell victim to an iceberg in 1912. Ever since this major incident, the shipping industry has prioritised safety from these icy masses.

Today, using artificial intelligence (AI) and machine learning, the International Ice Patrol (IIP) receives up-to-date iceberg forecasts each week. This group patrols the northwest Atlantic to monitor the sea ice and warn ships of any threats. Using these AI forecasts, ships are made aware of when the number of icebergs is expected to be high or low and of the likely path they will take through the water.

The computers involved in this system are built to analyse the sea surface temperature, atmospheric pressure and the mass balance of Greenland's ice sheet. Mass balance is a measure of how much mass has been added through precipitation and lost through events such as glacier calving. Previous data proves that when the sea surface temperature is colder and there are strong northwesterly winds, the number of icebergs is higher.

1 TITANIC ICEBERG
The famous iceberg that collided with the Titanic is thought to have been calved from Greenland in 1910 or 1911.

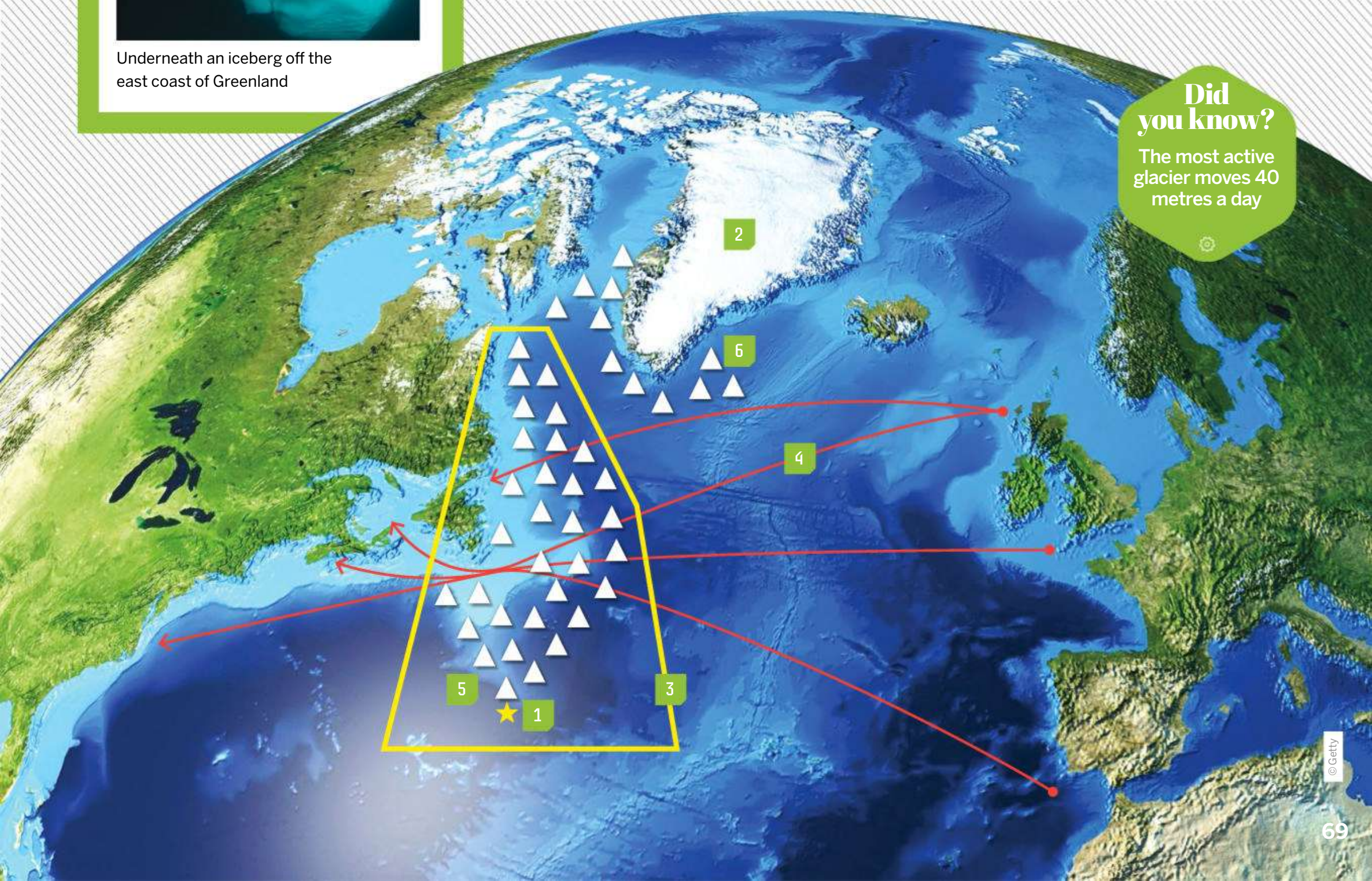
2 GREENLAND MASS
By incorporating data about the mass of Greenland's ice sheet, newly formed icebergs in busy shipping areas are considered.

3 OBSERVATION REGION
The IIP focuses its data around a latitude of 48 degrees north, where some of the busiest shipping lanes are.

4 TRANSATLANTIC SHIPPING LANES
Ships travelling between Europe and North American have a high risk of an iceberg encounter.

5 BEFORE AI
When the IIP first patrolled, workers would search for icebergs from their ships and remain stationed at the most southerly iceberg they could find, reporting on its movements.

6 FORECASTING
This technology currently creates forecasts for iceberg locations with an accuracy of around 80 per cent.



Did you know?
The most active glacier moves 40 metres a day

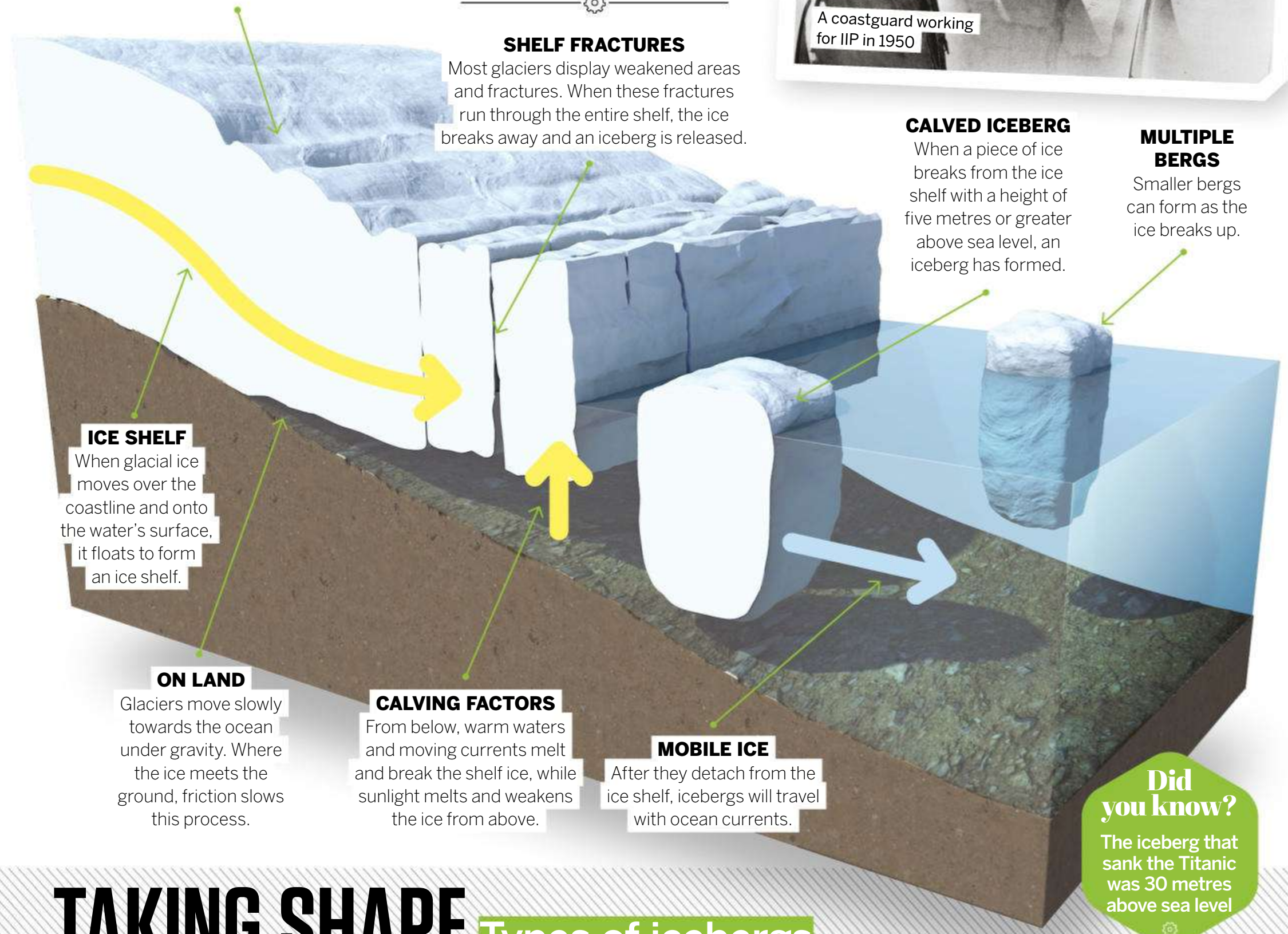
© Getty

GLACIER TO ICEBERG

How these free-floating frozen mountains are calved from ice shelves

ICE CAP
Continental glaciers, called ice caps, are formed over many centuries as layers of snow build up, increasing the pressure and compressing snow into ice.

SHELF FRACTURES
Most glaciers display weakened areas and fractures. When these fractures run through the entire shelf, the ice breaks away and an iceberg is released.

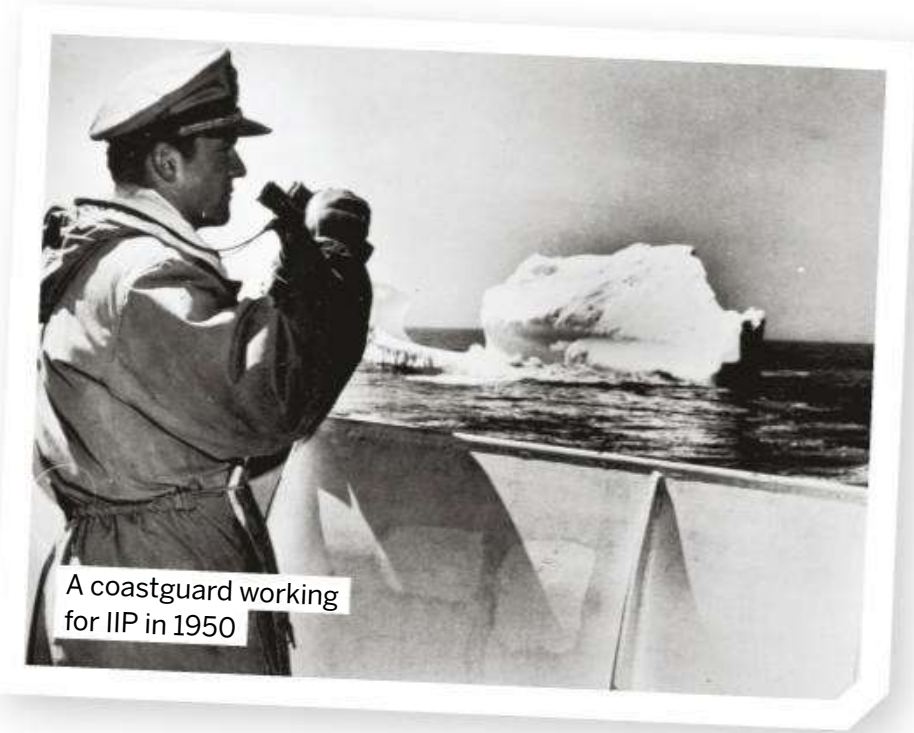


ICE SHELF
When glacial ice moves over the coastline and onto the water's surface, it floats to form an ice shelf.

ON LAND
Glaciers move slowly towards the ocean under gravity. Where the ice meets the ground, friction slows this process.

CALVING FACTORS
From below, warm waters and moving currents melt and break the shelf ice, while sunlight melts and weakens the ice from above.

MOBILE ICE
After they detach from the ice shelf, icebergs will travel with ocean currents.



A coastguard working for IIP in 1950

CALVED ICEBERG
When a piece of ice breaks from the ice shelf with a height of five metres or greater above sea level, an iceberg has formed.

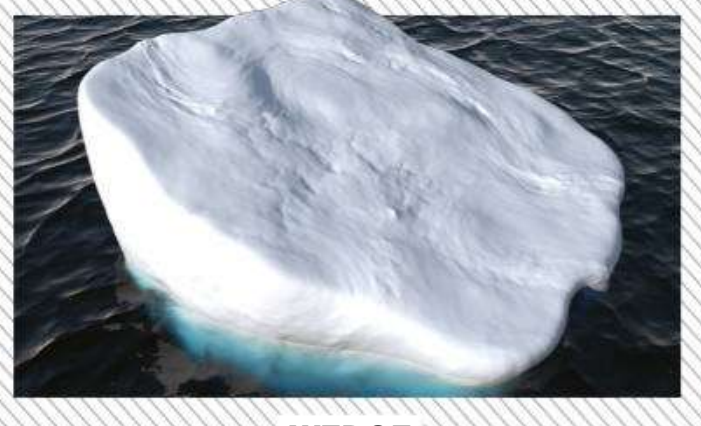
MULTIPLE BERGS
Smaller bergs can form as the ice breaks up.

Did you know?

The iceberg that sank the Titanic was 30 metres above sea level

TAKING SHAPE Types of icebergs

TABULAR
These icebergs have straight tops and sides. An iceberg's length-to-height ratio needs to be greater than 5:1 to be classed as tabular.



WEDGE
A flat-topped iceberg with a steep vertical side on one end, gently sloping to a lower height on the other end.

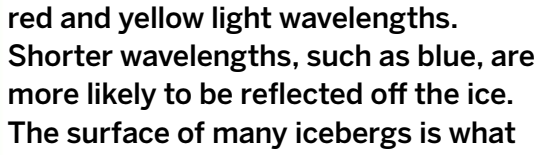
DOME
A smooth and rounded iceberg shape. Contact with the moving water and surface melting can produce smooth edges.

DID YOU KNOW? Antarctic icebergs are named using A, B, C and D, referring to the quadrant of the continent it calved from

WHITE, BLUE AND BLACK ICE

What colour is an iceberg? You might be tempted to say white, but icebergs can come in several different hues. What determines an iceberg's colour is how its structure and composition interact with light. Most often, an iceberg is blue in colour because pure ice, with few contaminants, absorbs red and yellow light wavelengths. Shorter wavelengths, such as blue, are more likely to be reflected off the ice. The surface of many icebergs is what provides them with their striking-white glow. But this is simply a disguising coat. The main body of an iceberg is often covered with tightly packed snow. Because snowflakes reflect all light wavelengths, the exposed surface of the iceberg is white.

Contrastingly, dense marine ice can create black icebergs. Without any cracks, the ice can't scatter the light that hits it, giving it a dark hue. Although the purest form of iceberg is blue, there are multiple colour variations. When cells from marine life or the iron from rocks is incorporated into the ice, icebergs develop green and yellow hues. And the cloudier the iceberg, the more air space there is within its structure.



The blue colour of glacial ice is visible where erosion has taken place

A-76: ICY GIANT

How the world's current largest iceberg formed from a giant slab

1 FILCHNER-RONNE ICE SHELF
This ice shelf is the second largest in Antarctica. A-76 came from its western side.

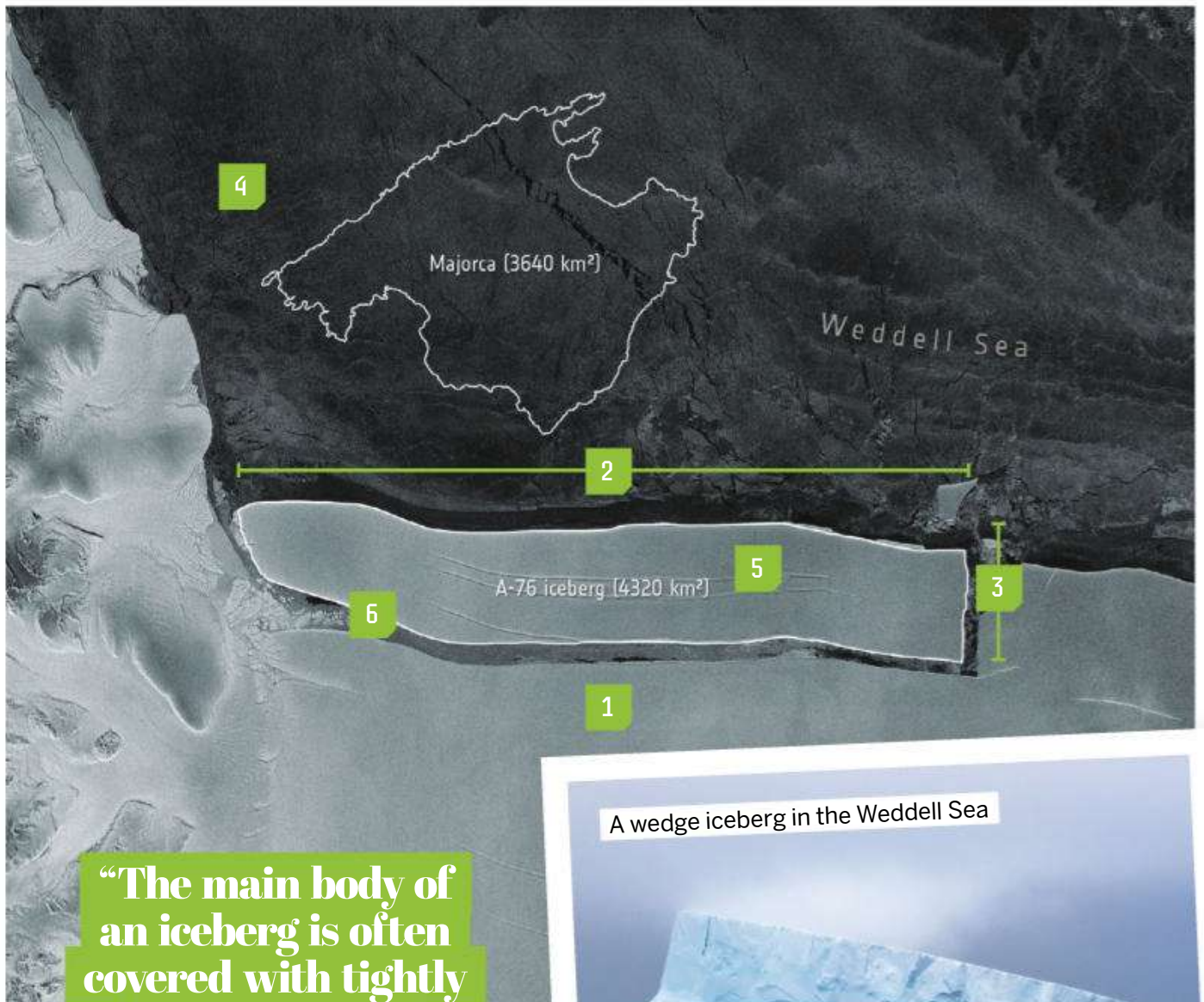
2 LENGTH
At around 110 miles in length, record holder B-15 dwarfed A-76 in size at 184 miles.

3 WIDTH
The iceberg is about 16 miles wide. Its shape is often compared to an ironing board.

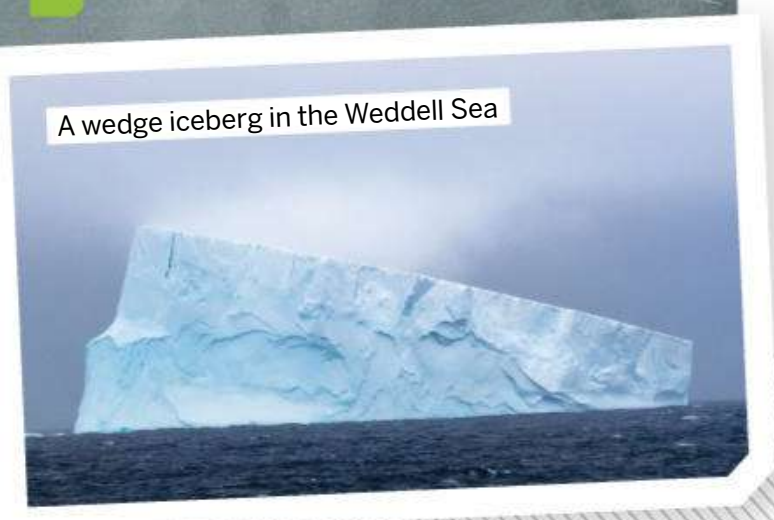
4 WEDDELL SEA
This sea is 1,200 miles wide, but it's covered largely by the permanent ice shelf.

5 TABULAR TYPE
The largest icebergs are often tabular, like A-76, because a significant length of the ice shelf is broken off.

6 SEPARATION
The 1,668-square-mile slab separated from the ice shelf in May 2021, becoming the world's current largest.



"The main body of an iceberg is often covered with tightly packed snow"



A wedge iceberg in the Weddell Sea

DRYDOCK
When an iceberg erodes mainly at the centre, a U-shape forms, also known as a drydock iceberg.

PINNACLE
Icebergs with one or more spires are known as pinnacle icebergs. Multiple occur when the iceberg becomes weathered near the middle.

BLOCKY
These are similar to tabular icebergs but have a closer length-to-height ratio. This gives blocky icebergs steeper sides.

© Getty / Illustrations by Adrian mann / ESA

WHY LEAVES TURN BROWN IN AUTUMN

Earth's deciduous plants lose their luscious green leaves during this changing of the seasons

WORDS **AILSA HARVEY**

In many parts of the world, the end of the summer season is marked by drastic changes in the trees' appearance. Leaves of red, orange, yellow and brown dance through the breeze before landing to create a crunchy layer on the ground. Autumn can produce distinctive colours, but for some plants it's a time to take drastic action for survival.

Evergreens aside, trees have very thin leaves. To keep them attached throughout winter would be dangerous as they would freeze – their cells would rupture and lose vital nutrients. The usual food-making process of converting sunlight and carbon dioxide into sugars is put on hold. The production of green cells called chloroplasts that enable this process is halted and nutrients are absorbed into the core of the tree to be utilised during the colder months. With this reduction of the core green cells, other pigments that exist in the leaves are given a season to paint the landscape with their bold colours.

Did you know?

Leaves take 6 to 12 months to decompose

On the ground, a leaf will decay as microbes in the soil help it decompose

WHAT TRIGGERS NEW COLOURS?

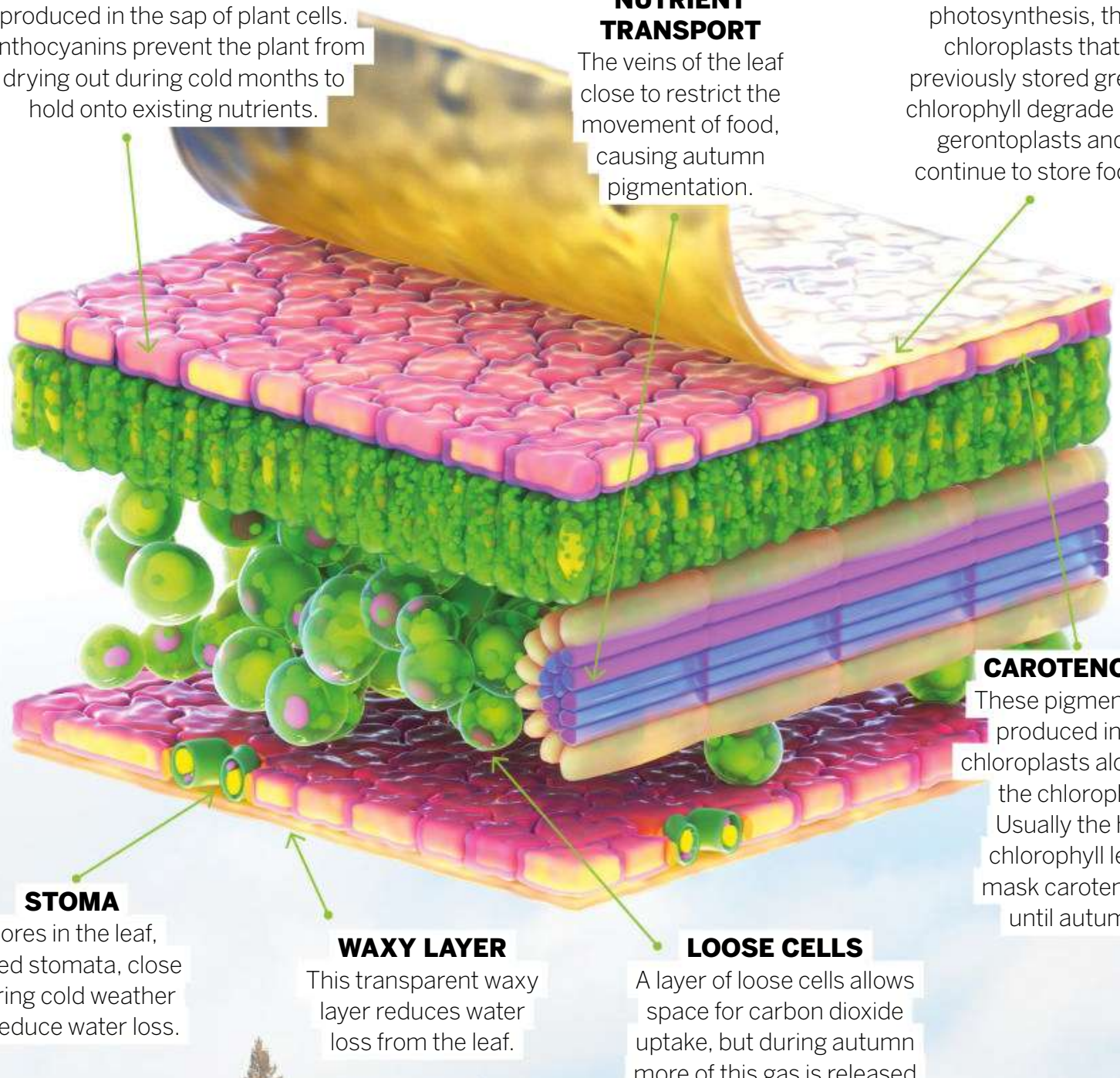
One of the most important factors in triggering these drastic changes is the amount of daylight available. As the days grow shorter and shorter, plants are unable to rely primarily on sunlight for their energy production. Secondly, the rate of photosynthesis decreases as the temperature plummets. The combination of these seasonal changes means that when autumn sets in, plants can't thrive using the same systems.

When the tree has absorbed the useful nutrients from a leaf, it detaches from the tree

DID YOU KNOW? When autumn includes moderate days and cool nights, autumn colours are most vivid

AUTUMN ANATOMY

The cells and structures that help leaves change colour



ANTHOCYANINS
Red and purple pigments are produced in the sap of plant cells. Anthocyanins prevent the plant from drying out during cold months to hold onto existing nutrients.

NUTRIENT TRANSPORT
The veins of the leaf close to restrict the movement of food, causing autumn pigmentation.

CHLOROPLASTS
When plants stop using photosynthesis, the chloroplasts that previously stored green chlorophyll degrade into gerontoplasts and continue to store food.

CAROTENOIDS
These pigments are produced in the chloroplasts alongside the chlorophyll. Usually the high chlorophyll levels mask carotenoids, until autumn.

STOMA
Pores in the leaf, called stomata, close during cold weather to reduce water loss.

WAXY LAYER
This transparent waxy layer reduces water loss from the leaf.

LOOSE CELLS
A layer of loose cells allows space for carbon dioxide uptake, but during autumn more of this gas is released from the leaf instead.

5 COLOURS IN THE AUTUMN PALETTE

1 BROWN
COMPOUND: **TANNINS**
These compounds are waste products of metabolic processes within the leaves. While they are always present, only when other pigment levels, such as chlorophyll and carotenoids, are low are these visible as brown hues.

2 RED
COMPOUND: **ANTHOCYANIN**
As chlorophyll is broken down, anthocyanins are produced. These produce leaves of red, purple and pink that are displayed on trees such as maples, oaks and sumacs.

3 ORANGE
COMPOUND: **CAROTENE**
Sugar maple trees turn a vibrant orange colour in autumn due to the increased concentration of carotene pigment. While chlorophyll diminishes with reduced light, carotene doesn't. This increases its concentration, and when combined with anthocyanin, different shades of orange are made.

4 YELLOW
COMPOUND: **XANTHOPHYLL**
This pigment is in a group called carotenoids, along with carotene. However, this pigment contains more oxygen and produces a light-yellow colour. Some of the trees that display xanthophyll in autumn include birches, beeches and aspens.

5 GREEN
COMPOUND: **CHLOROPHYLL**
Evergreen plants continue to photosynthesise during autumn. They retain their green colour year-round by continually producing chlorophyll – the green pigment that absorbs sunlight.

© Alamy / Getty

HOW SILK IS MADE

The science of silk ‘worms’ and how their fabric is harvested

WORDS **SCOTT DUTFIELD**

Silk being reeled from silkworm cocoons

Silk is one of the oldest textiles, dating back to 2700 BCE. Today more than 91,000 tonnes of silk is produced globally, with China and India being the two largest producers. The raw material for silk fabrics comes from domesticated silkworms, the larval stage in silk moth (*Bombyx mori*) metamorphosis. Despite their name, ‘silkworms’ aren’t actually worms. They are instead the white caterpillar larvae that emerge from the eggs laid by their moth mothers. Like any other species of moth, in order to transform into a winged adult, they must spin a cocoon in which they will anatomically transform.

To spin a cocoon, silkworms secrete a sticky protein called fibroin from two salivary glands called sericteries. Once the fibroin is exposed to oxygen in the air, it solidifies into a thread. A secondary protein called sericin is also secreted, acting as the glue that holds threads of silk together. The oval shape of the cocoon is created by silkworms spinning a continuous strand of silk, folded in a figure-eight pattern around their bodies. It takes a single strand of silk that averages around 915 metres in length to complete the cocoon.

Did you know?

A female silk moth can lay between 300 and 500 eggs

Silkworms can spend over a month in the cocoon to pupate and transform into an adult moth and emerge with wings. However, in the most common method of silk production, called sericulture, the cocoon is unravelled to spin textiles before the larvae have fully developed and broken through the cocoon.

UNLIKELY SPINNERS

Bees, ants and beetles also produce fibrin during their larval stages. Honey bees (*Apis mellifera*) produce silk to reinforce the wax cells within the hive while they pupate into adults, while red bull ants (*Myrmecia gulosa*) also use their silk to spin protective cocoons during their development. Weaver ants (*Oecophylla smaragdina*) have found a use for their silk not only during their larvae phase, but as adults. As tree-dwelling insects, these ants nest between leaves. To create a protective nest, adult ants will take silk produced from the larvae and use it as a sticky thread to bind leaves and construct a nest.

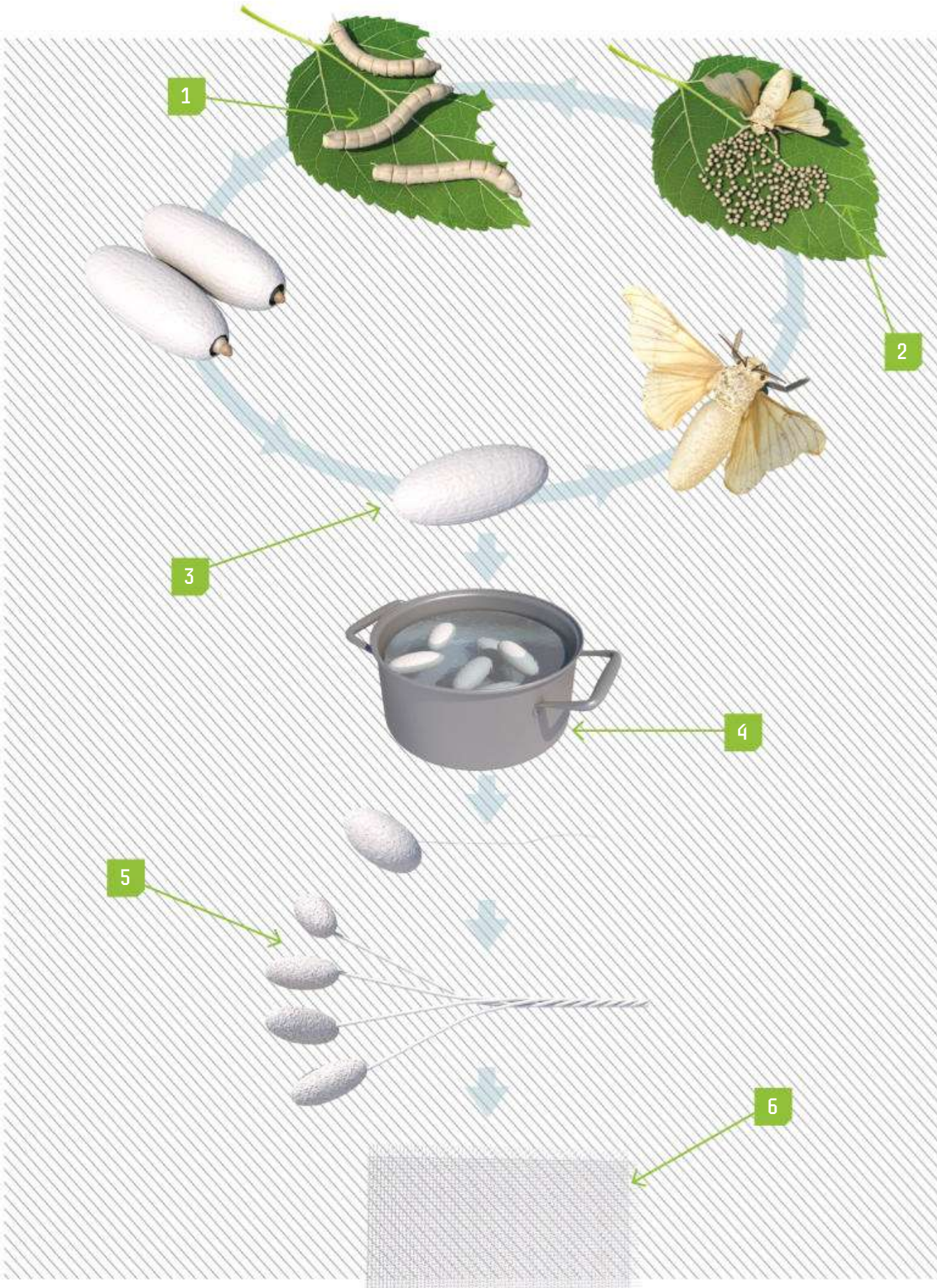
A colony of weaver ants constructing a nest out of larvae silk

Lotus silk being extracted from lotus plants in Myanmar

LOTUS SILK

The lotus (*Nelumbo nucifera*) is not only the national flower of India, but also the source of one of the rarest silks on Earth. Below the pastel-pink petals of this water-dwelling plant is a stem filled with silk-like fibres. Lotus silk is one of the rarest and most expensive fabrics in the world due to the painstakingly delicate process required to extract it. By hand, stems are snapped and twisted to expose the fibres. There are only around 30 fibres per plant. These are drawn out, rolled by hand and left to dry. Silk harvesting has to be done within 24 hours while the stem is still wet and silk can be extracted. This is a time-consuming process that produces a small amount of very delicate silk, hence its high value. A scarf around 1.7 metres long and 30 centimetres wide requires the silk from more than 9,000 lotus stems.

DID YOU KNOW? It takes around 2,500 silkworms to make 450 grams of silk



HOW SILK IS HARVESTED

The process of unravelling silkworm cocoons

1 SILKWORM

After only seven days, three-millimetre-long silkworm larvae hatch from eggs.

2 MULBERRY LEAVES

As larvae, silkworms spend their time feeding predominantly on mulberry leaves. They can only eat as larvae, losing their mouthparts as they become adults.

3 COCOON

After around 30 days of devouring mulberry leaves, silkworms spin their cocoons. After a few days the cocoons harden, and it's time to harvest the silk.

4 BOILING

To break down the cocoon, silk farmers place them into hot water. This kills the pupae inside and separates the silk fibres from the sericin glue.

5 REELING

Between 6 and 12 cocoons are put together; their silk threads are reeled to form a denser thread.

6 COLLECTION

The raw silk threads are then twisted and doubled to the desired thickness and spun into fabrics.

An adult silk moth, native to China

Racks of silkworm cocoons ready to have their silk extracted

© Getty / Illustration by Adrian Mann

HOW TO BREATHE IN SPACE

Space is an airless vacuum, but thanks to technology, astronauts can breathe as easily as they do on Earth

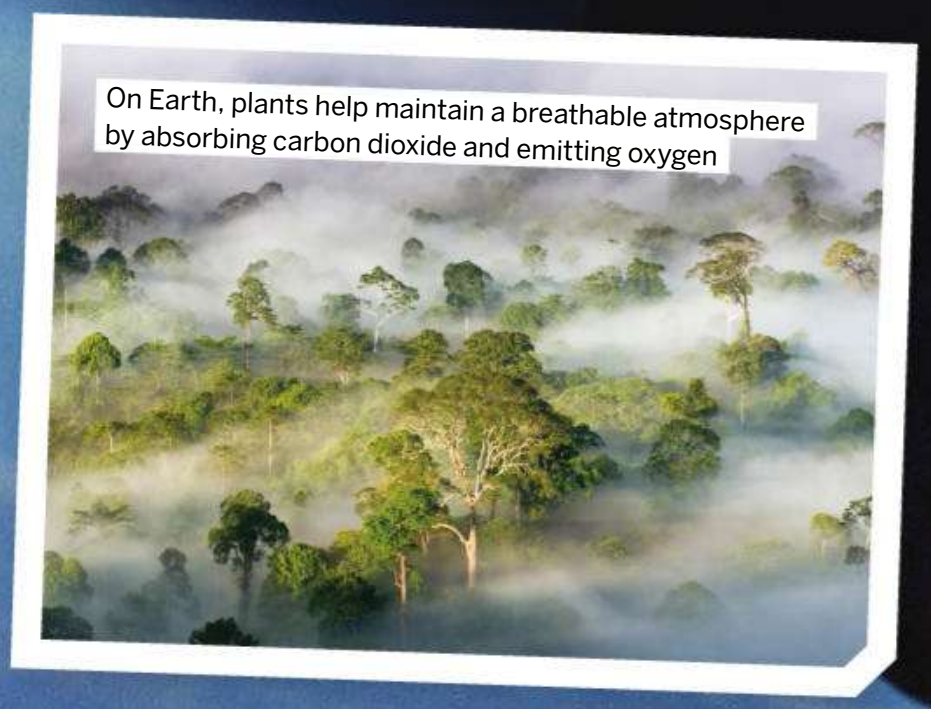
WORDS **ANDREW MAY**

DID YOU KNOW? Early space missions were so brief they could carry all the oxygen they needed in storage tanks

From the perspective of humans, space is an extremely hostile environment, with hazards ranging from deadly radiation to a lack of gravity. But perhaps the most obvious problem of all is the fact that space is a vacuum. On Earth, we take breathing for granted. We're immersed in an atmosphere that gives us the essential gas – oxygen – that we need to stay alive. In fact, Earth's atmosphere is a mixture of gases, containing around 21 per cent oxygen and 78 per cent nitrogen, with the remaining one per cent made up of various other gases. From our point of view, however, oxygen is the thing that really matters. Although we're constantly absorbing it, along with other animals, it's continuously replenished thanks to plants, which produce oxygen through photosynthesis.

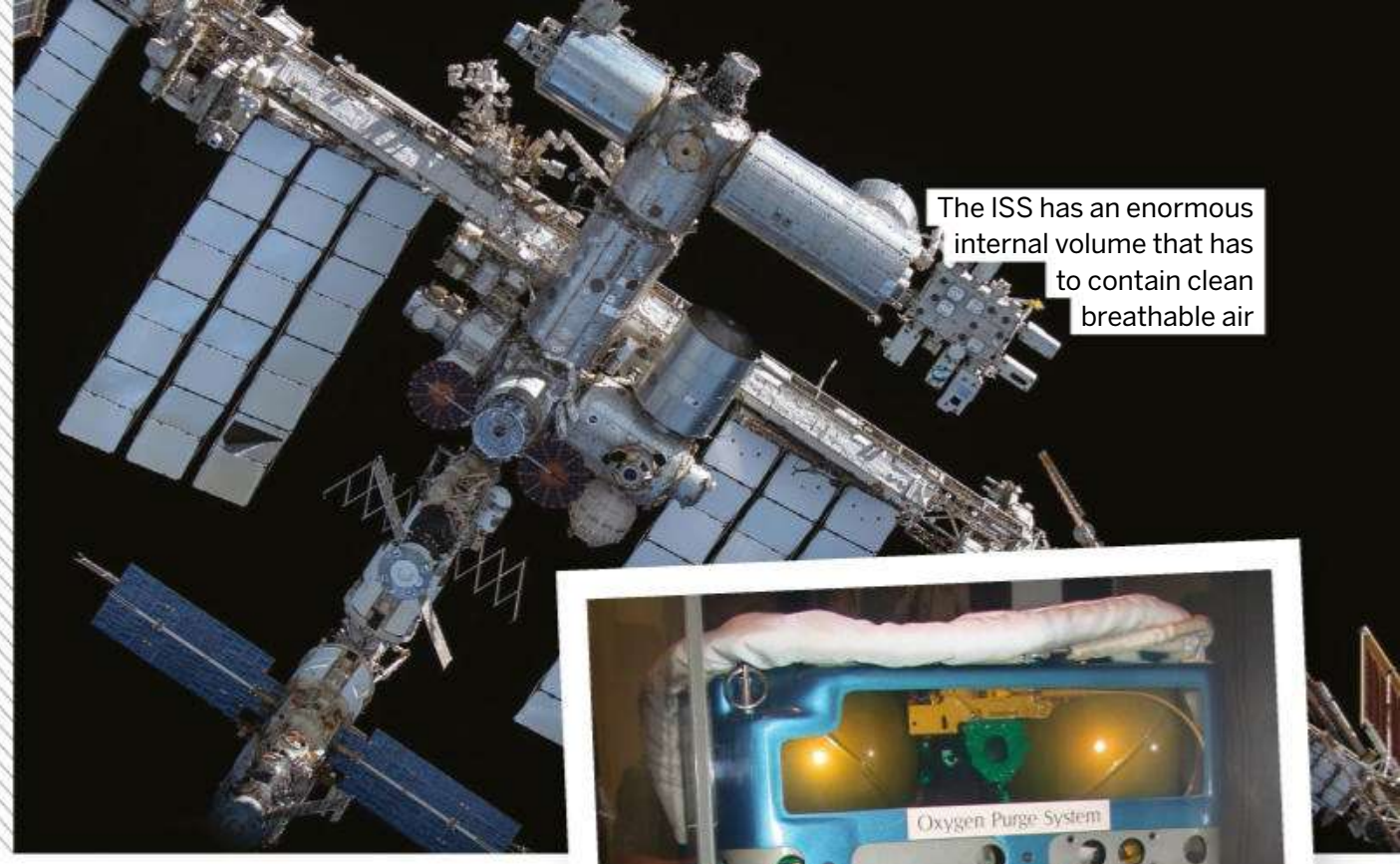
When we breathe in, the oxygen taken into our lungs is absorbed into the bloodstream. But that's only half the story. Our body produces carbon dioxide (CO_2) as a waste product, and this is exhaled when we breathe out. This CO_2 creates another hazard in itself if there's too much of it, so maintaining a healthy atmosphere involves removing CO_2 as well as adding fresh oxygen.

The first person to seriously consider the problem of breathing in space was Jules Verne in his 1865 novel *From the Earth to the Moon*. For his fictional spaceflight, he described a chemical-based 'life-support' system in which heated potassium chlorate releases oxygen into the atmosphere, while potassium hydroxide absorbs excess CO_2. While this isn't the exact system used in real spacecraft, Verne's basic principle – that a breathable atmosphere can be maintained via chemical technology – is completely valid.


On Earth, plants help maintain a breathable atmosphere by absorbing carbon dioxide and emitting oxygen

© Alamy

LIFE-SUPPORT TECHNOLOGY



The ISS has an enormous internal volume that has to contain clean breathable air

The air inside the International Space Station (ISS) is kept at a similar pressure to Earth's atmosphere at sea level and is made up of a similar mixture of gases: around 20 per cent oxygen and 80 per cent nitrogen. The astronauts inside are able to breathe as easily as we can down here on the surface of the planet, and they have been doing so on a continuous basis ever since the ISS was first occupied in November 2000. That's all thanks to the ingenious technology that maintains a healthy atmosphere inside the space station.

A critical component of any crewed space vehicle is its Environmental Control and Life Support System, or ECLSS for short. This is a complex network of machinery, pipes, tanks and sensors designed to provide astronauts with all the air and other life-support essentials they need. Unsurprisingly, the most complex ECLSS of all is the one found on the ISS, which is required to support its unprecedented internal pressurised volume of more than 900 cubic metres.

As well as maintaining a breathable atmosphere, the ISS' ECLSS includes a water recovery system that captures, purifies and recycles water both from cabin humidity and from crew members' urine. As gross as the latter sounds, the result is perfectly drinkable. "Today's coffee was yesterday's pee," as astronaut Tim Peake put it. There are other bodily side-effects that ECLSS has to deal with, too, such as the nasty smells from gas and sweat. The offending gases – methane and ammonia respectively – are removed using activated charcoal filters.

Recycling water, as well as constantly replenishing it with fresh supplies from Earth, is important for more than just drinking. It also provides the astronauts' main source of oxygen for breathing thanks to the fact that every water molecule contains an atom of oxygen. Its chemical formula is H_2O – two atoms of hydrogen and one of oxygen. These can be separated using a process called electrolysis, which involves passing an electric current through the water to split it into molecules of hydrogen and oxygen – two of the first and one of the second for every two molecules of water.

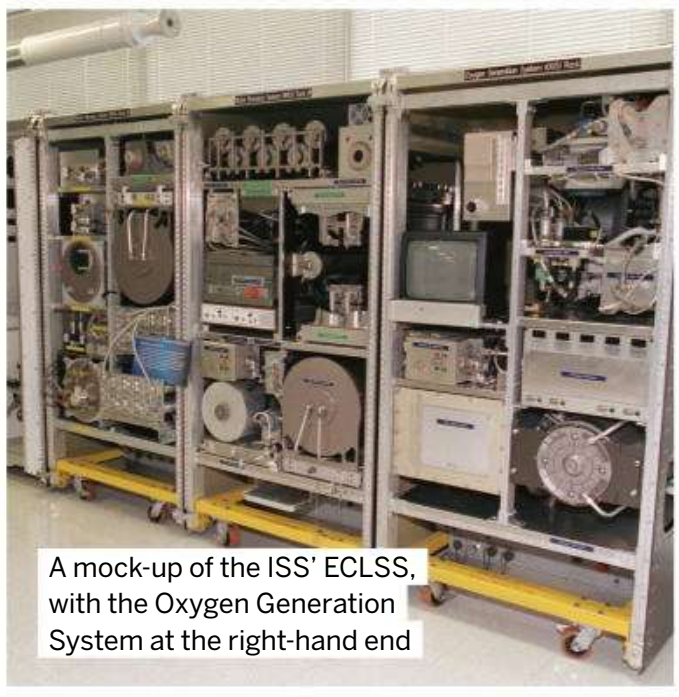
Did you know?

The ISS contains as much air as a Boeing 747 airliner

After discarding the hydrogen, what's left is breathable oxygen.

A similar process is also used to generate oxygen on submarines, which have no shortage of water to electrolyse. Submarines also share the ISS' problem of having to remove excess carbon dioxide – a well-established process known as CO_2 scrubbing. Various technologies are available for this, including the use of potassium hydroxide as suggested by Jules Verne in his novel. This – and related chemicals such as soda lime and amines – have a propensity to lock on to CO_2 molecules, thus removing them from the atmosphere. The ISS, on the other hand, uses a different method for CO_2 removal involving a type of mineral called zeolite. The airflow inside the space station takes it over a bed of zeolite, causing CO_2 and water to stick to the mineral while everything else passes through unhindered. The water is then retrieved for recycling, while the CO_2 is ejected into space.

When astronauts go outside the ISS to perform a spacewalk, or extravehicular activity (EVA), they breathe pure oxygen rather than the usual oxygen-nitrogen mix. The spacesuits they use are effectively self-contained life-support systems, complete with their own oxygen supply as well as electrical power, a ventilating fan and an in-suit drink bag.



A mock-up of the ISS' ECLSS, with the Oxygen Generation System at the right-hand end

A display mock-up of the interior of the Apollo PLSS, with major parts labelled

WALKING ON THE MOON

The most famous extravehicular activities of all were the moonwalks carried out by the Apollo astronauts between 1969 and 1972. These were longer than many people realise. On the final mission, Apollo 17, the astronauts spent a total of 22 hours in spacesuits outside the Lunar Module in the course of three separate EVAs. This presented a major challenge in terms of life support, with each astronaut completely reliant on the Portable Life Support System (PLSS) in their backpacks.

Unlike modern spacecraft, the Apollo missions used pure oxygen at reduced pressure rather than an earthlike oxygen-nitrogen mix. This was also true of the lunar EVA suits, where the internal pressure was just a quarter of atmospheric pressure. In addition to the main oxygen tanks, the PLSS contained a backup oxygen purge system and a lithium-hydroxide scrubber to remove excess CO_2.

DID YOU KNOW? If resupply missions were halted, the ISS would run out of food before it ran out of water or oxygen

DANGERS OF CO_2 BUILDUP

Without effective scrubbing technology, astronauts would soon face ill health from exhaled CO_2

VOLUME OF CO_2 IN AIR

- 1%
- 3%
- 5%
- 8%

2 REDUCED HEARING
Hearing can be affected even at relatively low CO_2 concentrations.

5 DROWSINESS
The first indication that CO_2 laevels are rising is a feeling of drowsiness.

6 MILD NARCOSIS
A feeling of mild intoxication may occur even at low CO_2 concentrations.

7 DIZZINESS
As the concentration rises to moderate levels, astronauts may experience dizziness, confusion and headaches.

1 DIMMED SIGHT
One of the symptoms that occurs at high CO_2 concentrations is dimming of vision.

8 UNCONSCIOUSNESS
At a concentration of eight per cent or higher there's the real risk of loss of consciousness.

4 MUSCULAR TREMORS
Another symptom associated with high CO_2 levels is the occurrence of muscular tremors.

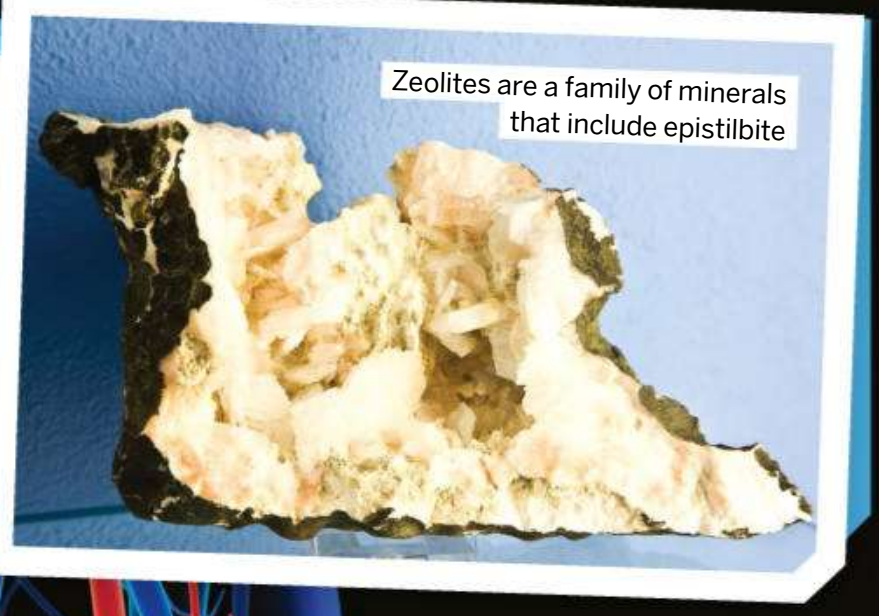
3 SHORTNESS OF BREATH
At moderate concentrations, astronauts may experience difficulty breathing.

9 SWEATING
Excessive perspiration can also occur at high CO_2 concentrations.

10 RAPID HEART RATE
Even at relatively low CO_2 levels there may be an increase in heart rate and blood pressure.

ZEOLITE

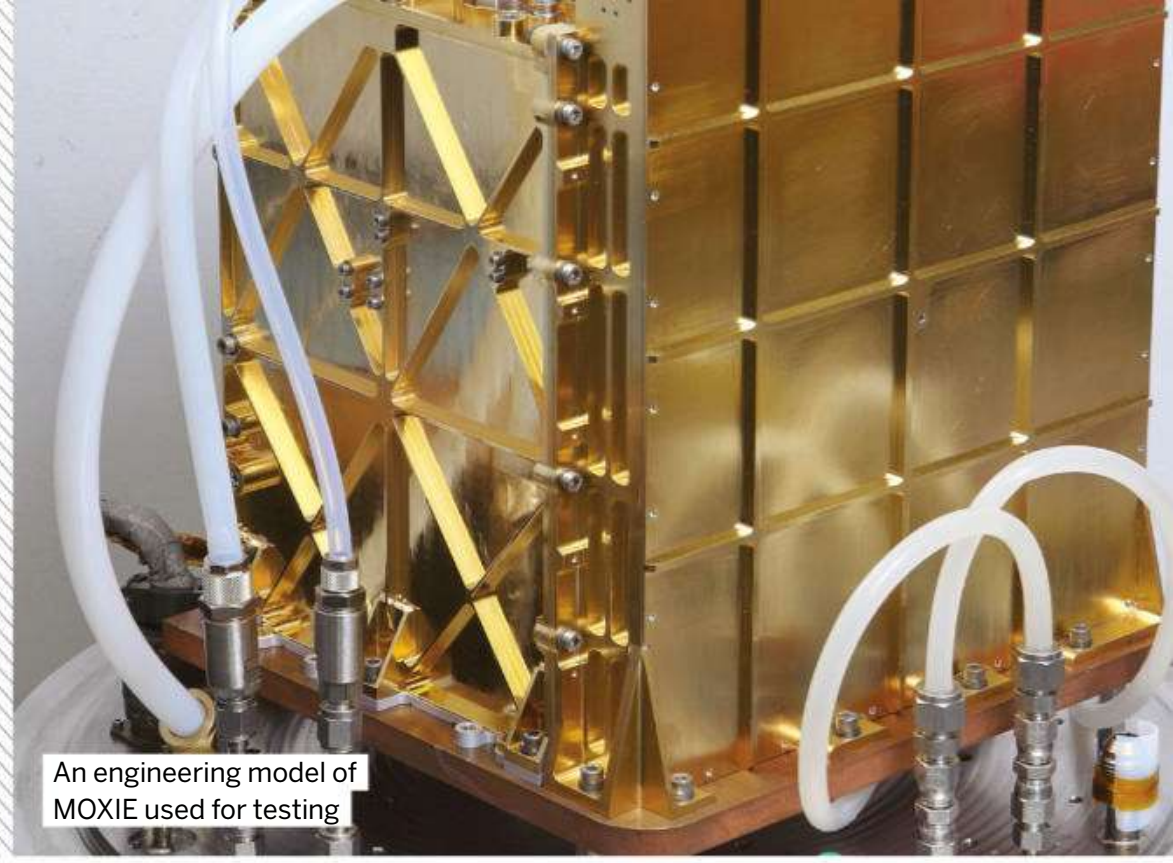
The CO_2 scrubbers on the ISS make use of a sponge-like mineral called zeolite, filled with tiny pores that can trap CO_2 molecules. The zeolite then expels the captured CO_2 when it's exposed to the vacuum of space. Zeolite is made up of a combination of aluminium, silicon and oxygen atoms arranged in such a way as to act as a kind of molecular sieve, since only very small molecules are able to pass through its pores, while larger ones get trapped. The zeolite used on the ISS has pores that are just small enough to trap CO_2 and water molecules – the latter being saved for recycling – while passing other atmospheric gases unhindered.



Zeolites are a family of minerals that include epistilbite

© Alamy / NASA

IN-SITU RESOURCE UTILISATION


An engineering model of MOXIE used for testing

Though the ISS recycles as much as possible, it still requires regular shipments of water, oxygen and other supplies from Earth. At around 250 miles altitude, it's close enough to make regular resupply missions practical. But that won't always be the case for future space endeavours, such as trips to Mars or a permanent base on the Moon. In such cases, it will be much easier if all the necessities – including air for breathing – can be sourced locally. This is the idea behind in-situ resource utilisation, or ISRU, the practice of collecting, processing, storing and using resources on other astronomical bodies instead of shipping them all the way from Earth.

When NASA's Perseverance rover touched down on Mars in February 2021, it carried a small-scale ISRU demonstrator called the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE), designed to convert CO_2 from the thin Martian atmosphere into breathable oxygen, which it can do at roughly the same rate as a small tree on Earth. If successful, a much larger version of MOXIE could be placed on Mars to create a store of oxygen that would be ready and waiting prior to the first human landing.

The MOXIE prototype is about the size of a car battery, with a mass of 17 kilograms. It's designed to produce up to ten grams of oxygen per hour – effectively taking the O_2 out of CO_2, which makes up about 96 per cent of the Martian atmosphere. It does this using a form of electrolysis, a technique also utilised in the context of extracting oxygen from water. The process used in MOXIE, which is analogous but slightly different, is called solid oxide electrolysis.

The first step is to take in a quantity of CO_2 from the Martian atmosphere using MOXIE's CO_2 Acquisition and Compression (CAC) subsystem. As well as drawing gas in, the CAC compresses it to around half of Earth's atmospheric pressure, which is much higher than the ambient pressure on Mars. The CAC also filters out the dust particles that are always blowing around in the Martian atmosphere.

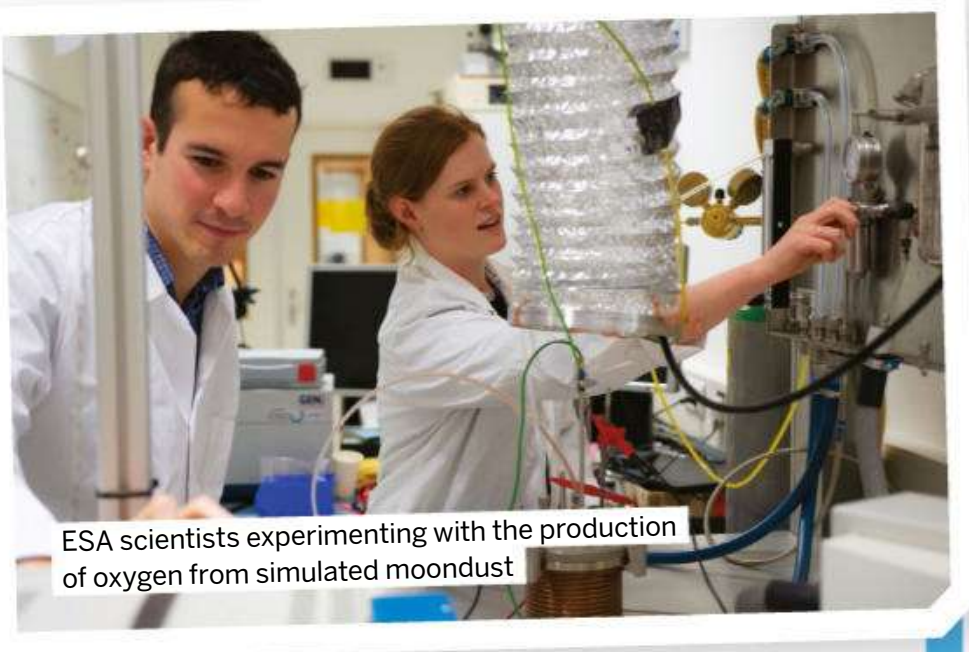
After the CAC, the next step is the Solid Oxide Electrolysis (SOXE) subsystem itself. Operating at a temperature of around 800 degrees Celsius, this instrument uses a stack of ten electrolytic cells to break CO_2 down into carbon monoxide – which is discarded as a waste product – and oxygen. MOXIE's third and final subsystem, Process Monitoring and Control (PMC), looks after things like flow rate and temperature, as well as monitoring and recording data from MOXIE's sensors.

After a year and a half of operation, MOXIE is fully living up to its designers' expectations. In the course of seven experimental runs, spanning both day and night and the different seasons of the Martian year, the prototype has consistently been able to produce at least six grams of breathable oxygen per hour.

Efficient use of in-situ resources will be essential for permanently occupied Moon outposts

OXYGEN ON THE MOON

Unlike Mars, the Moon has no atmosphere, so a MOXIE-style system to extract oxygen from CO_2 isn't going to work there. Yet there's a reasonable prospect that humans will be visiting the lunar surface for lengthy stays in the not-too-distant future. They're going to need oxygen to breathe, and shipping it all the way from Earth is a very expensive option. Is there any way to create oxygen up there on the Moon via ISRU? It turns out the answer may be yes, according to the European Space Agency's Materials and Electrical Components Laboratory in the Netherlands. A surprising fact revealed by the Apollo missions is that moondust is made up of 40 to 45 per cent oxygen – its single most abundant element, in fact. ESA scientists have demonstrated a method for extracting this oxygen using a form of electrolysis, thus making lunar ISRU a real possibility.


ESA scientists experimenting with the production of oxygen from simulated moondust

DID YOU KNOW? The crew of Soyuz 11 died because the air leaked out of their spacecraft

5 FACTS ABOUT LIFE SUPPORT

1 BEFORE THE SPACE AGE
Earth's atmospheric pressure decreases with increasing altitude, so even before the days of space travel high-flying pilots needed life-support garments resembling spacesuits.

2 DIFFERENT SPACECRAFT, DIFFERENT ATMOSPHERES
When an Apollo and Soyuz craft linked up in orbit in 1975, they needed an airlock between them because they used different atmospheric compositions.

3 SPY SUITS
For the first flight of the Space Shuttle, NASA had no suitable spacesuits available for the crew. They wore pressure suits intended for spy plane pilots instead.

4 BACKUP SYSTEM
Regular resupply missions bring tanks of oxygen to the ISS. These are stored outside the station's airlock just in case they're needed to compensate for any leaks that may occur.

5 A SPACEBORNE ECOSYSTEM
The European Space Agency's Micro-Ecological Life Support System Alternative (MELiSSA) project is working on a future life-support system that uses plants and other organisms to produce oxygen and water.

MOXIE ON MARS

MOXIE is NASA's first ISRU experiment on the Red Planet

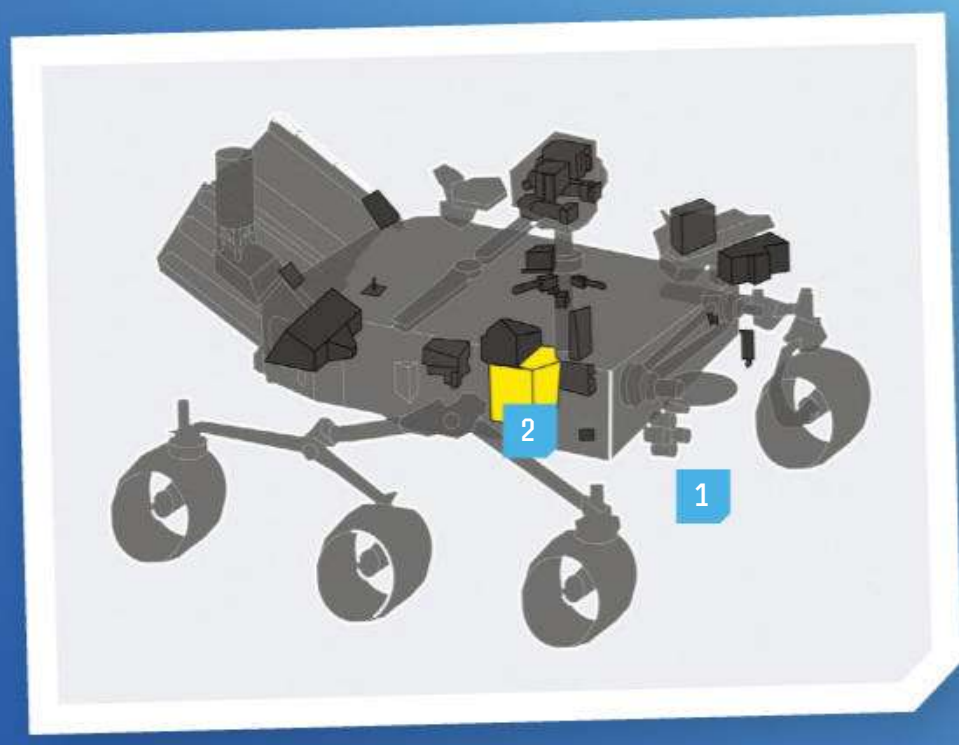
1 PERSEVERANCE ROVER
MOXIE is just one of the many experiments and scientific instruments on board the latest NASA rover.

2 MOXIE
The experiment is located near the front of the rover on the right-hand side.

3 SCROLL COMPRESSOR
This is used to compress the tenuous Martian atmosphere to higher pressures.

4 SOXE ASSEMBLY
This is the heart of MOXIE, which produces oxygen through solid oxide electrolysis.

5 SENSOR PANEL
Most of MOXIE's sensors and flow control devices are located on this assembly.



Did you know?
The Martian atmosphere only contains 0.16 per cent oxygen

© Alamy / ESA / NASA

Win!

A CODING ROBOT WORTH £199.99

This month we're giving you the chance to win a Ginobot Coding Lab Robot. This smart programmable robot allows children to explore the world of STEAM and create their own robotic configurations using building blocks, motors and sensors. There are also several experiments to perform with the Ginobot to test out your coding ability

For your chance to win, answer the following question:

Which of these robots appeared in the *Star Wars* franchise?

A: HAL 9000 B: WALL-E C: R2-D2

Enter online at **howitworksdaily.com** and one lucky entrant will win!

Terms and Conditions: Competition closes at 00:00 GMT on 22 December 2022. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **www.futuretcs.com**. Entries must be received by 00:00 GMT on 22/12/2022. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

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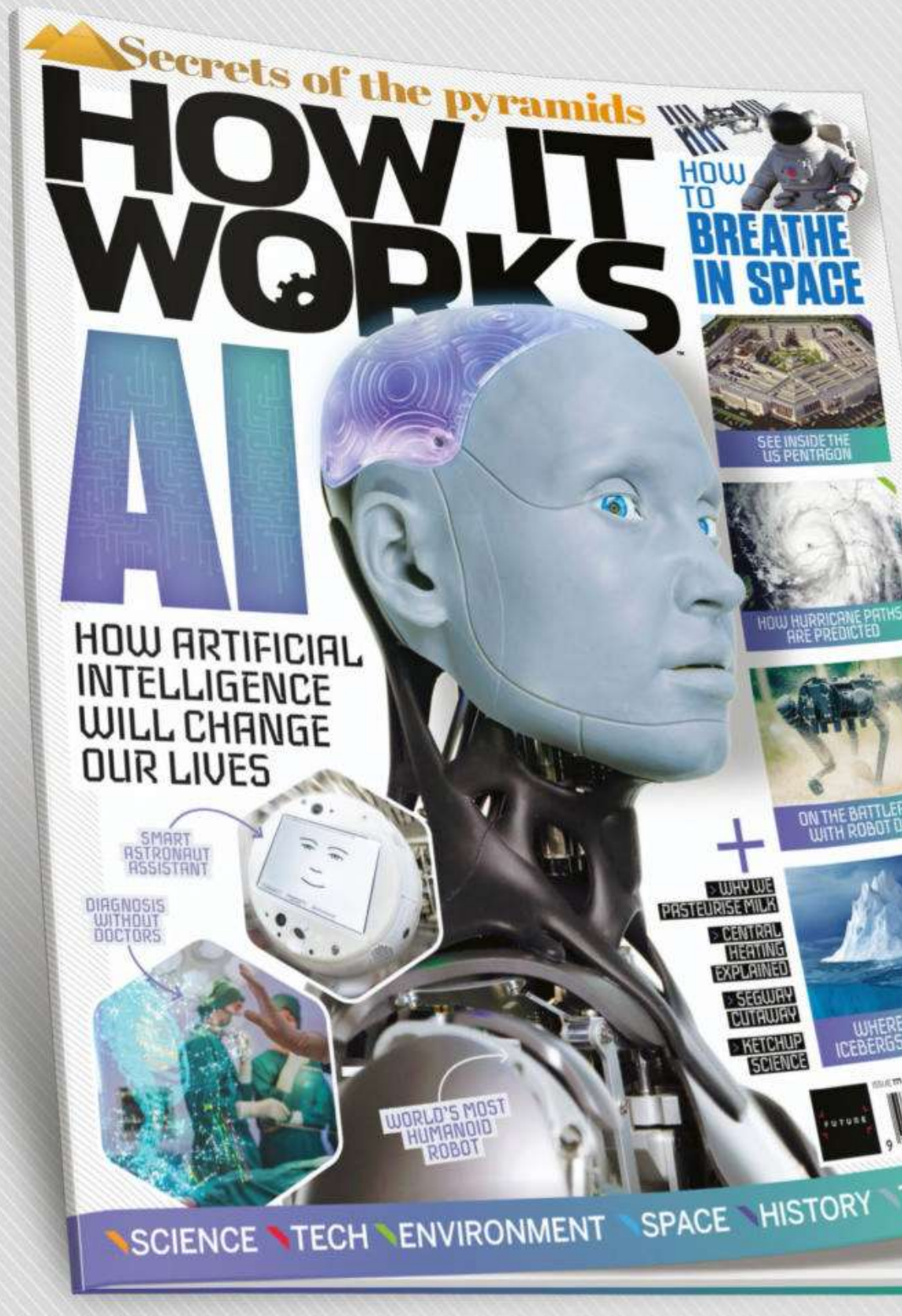
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BRAINDUMP

Amazing answers to your curious questions

How many animals have been to space?

Carol Ann

Due to the large numbers of eggs, bacteria and small insects involved, it's difficult to give an accurate answer to this, but the final figure is quite large – certainly several hundred. During the 1950s and 1960s, the USSR alone sent over 50 dogs into space. Over 30 monkeys have been sent into space by the US, USSR and France. Monkey astronaut names included Mike, Patricia, Baker, Abel, Martine, Pierette, Zabiyaka, Ivasha, Lapik and Multik.

HOW DO NANOTECHNOLOGY FACELIFT CREAMS WORK?

Romana Richards

There is little research available in terms of scientific publishing to suggest that the nanotechnology in facelift creams works. Either the companies involved are very protective of their secret formula, or it's not actually working. 'Nano' means small, very small, to be exact, and thereby nanotechnology is about engineering materials on the scale of molecules and atoms. Here we are talking about a cream which can supposedly 'lift' the face and tighten it somehow. While there's no doubt as to the ability of these creams to moisturise, improve the texture of the skin and temporarily tighten the skin, the ability of a cream to perform this tightening and lifting permanently – which would otherwise be done through surgical means – remains in doubt.

HOW DOES KEVLAR STOP A BULLET?

Tom Boon

Kevlar is able to stop a bullet due to its molecular structure. It's a light polyarylamide plastic fabric that has a high tensile strength. This means it takes a huge amount of energy to make its fibres stretch even a little. Each Kevlar molecule looks like a long twisting coil. During polymerisation these coils of molecules become tangled, causing them to be hard to stretch. Inside a bulletproof vest are many strips and layers of Kevlar. When a bullet hits the vest, it tries to force itself through the layers, but to do this it must push the fibres apart. The fibres are woven and resist this very effectively. The movement is translated into a stretching force on the fibres. Some will break, but most will absorb the energy of the bullet by stretching a small amount.

WHAT ARE HALLUCINATIONS?

Bob Lowe

Hallucinations are perceptions in a conscious and awake state that are not the result of external stimuli but have the qualities of real perception. They are, by their nature, incredibly vivid. Most people think of visual hallucinations, but they can affect almost all of our sensory experience. They can be centred around our five common senses, but also our balance, nervous system, our understanding of our body and its proportions, temperature and the perception of time.

In humans, hallucinations are often the result of the consumption of psychoactive substances such as lysergic acid diethylamide (LSD) or dimethyltryptamine (DMT). DMT occurs naturally within the brain in small quantities. Dr Rick Strassman put forward the theory that the release of DMT from the pineal gland was responsible for near-death experiences, and it has also been linked to some dream experiences. Hallucinations can also be triggered by a high fever, and the release of DMT could again be a factor in this.

Did you know?
Hearing voices or noises is an auditory hallucination

What is an itch?

Lewis Johnson

An itch is a built-in defence mechanism that is designed to alert your body to potential harm. It starts because a stimulus such as a bug or leaf comes into contact with your skin and rubs back and forth against it. This causes irritation and triggers fibres from your skin to send signals to your brain. Your natural reaction to this is to scratch the area to remove the irritant.

© Alamy / Getty

BRAINDUMP

Did you know?
Slow worms are native to Western Europe

HOW DOES A SLOW WORM CUT ITS OWN TAIL OFF TO EVADE PREDATORS?

Ross Woodley

Slow worms, like many other lizards, have a tail that can be broken as part of their defensive mechanism as an escape strategy. The scientific term for this phenomenon is 'autotomy' – auto meaning self, and tomos to cut – and is the self-induced releasing of a specific body part. One of their tail vertebrae is actually broken in half. Its tail separates at a 'fracture plane', one of many fracture planes that are regularly spaced along the length of the tail, either in between vertebrae or in the middle of each vertebrae.

It doesn't end there – the predator's attention is directed to the tail 'twitching' back and forth as the lizard remains still or slowly repositions itself so as to launch itself away from the predator. The negative side to this is that tail loss is costly. No slow worm wants to lose its tail unless its life is seriously in danger. Losing a tail represents a loss of fat and protein, both stored in the tail and that which is dedicated towards the regrowth of a new tail. Losing a tail when young actually puts a young slow worm at a higher risk of being preyed upon again shortly afterwards. The tail eventually regrows, but is cartilaginous as opposed to skeletal.

While autotomy is costly in terms of the overall loss to the lizard, it's apparently quite effective as a survival strategy, as this defence strategy is fairly widespread through the lizard families. Incidentally, the 'fragilis' in the Latin name for the slow worm, '*Anguis fragilis*', refers to the fragile nature of its tail.

Why does the grass grow in summer and not in winter?

Andy White

Very simply, grass doesn't grow as fast in winter largely because of the lower temperatures. To a lesser extent, lower light levels from less intense and shorter days also mean that the plant is much less metabolically active. Nutrients may be less available, and so what resources are being made are largely used to maintain the plant rather than significantly add to its growth.

WHAT'S THE DIFFERENCE BETWEEN SPORES AND SEEDS?

Pam Daniels

Both spores and seeds perform a similar function – the dispersal of the organism. They differ in several ways. Seeds are produced by flowering plants and gymnosperms like conifers; they are the result of sexual reproduction and consist of an embryo enclosed by a protective coat. Spores are the reproductive bodies of cryptogamic plants and are produced in a variety of ways. They are usually microscopic and may be single cells or multicellular.

WILL THE INTERNET EVER GET FULL?

@suenatal

There's an ongoing debate about this, and experts are divided in opinion. Every person who starts up a website must obtain an IP address, which allocates them their 'space' on the internet. When the internet first began, the number of available IP addresses seemed inexhaustible at approximately 4.3 billion, but that was long before there was a computer in most households. As time goes by, more and more IP addresses are being used up, and we could still run out. This doesn't necessarily mean there won't be any more space available, but a new system will have to be put in place to allow for more addresses. The latest system is called Internet Protocol Version 6 (IPv6) and can potentially house approximately $3x10^{34}$ addresses – a three followed by 34 zeros.

Is the world really round?

Mike Williams

If the world's surface could be smoothed out and the tides ceased, our planet would be a shape called an 'oblate spheroid', or a squashed sphere bulging around the equator. In reality, Earth doesn't have a uniform shape, as there are higher parts (mountains) and lower parts (oceans). The term for this type of generalised shape is a 'geoid', although the variation of Earth's surface to the averaged out geoid surface is very small – less than the relative thickness of an apple skin to an apple.

WHY DO SOME PEOPLE HAVE ALLERGIES?

@jellyjobean

Allergies can be caused by two things: host and environmental factors. Host is if you inherit an allergy or are likely to develop one due to your age, sex or racial group. Environmental factors can include things such as pollution, epidemic diseases and diet. People who are likely to develop allergies have a condition known as 'atopy'. Atopy is not an illness, and is instead an inherited feature that makes individuals more likely to develop an allergic disorder. Atopy tends to run in families. The reason why atopic people have a tendency to develop allergic disorders is because they have the ability to produce the allergy antibody called 'immunoglobulin E', or 'IgE', when they come into contact with a particular substance. However, not everyone who has inherited the tendency to be atopic will necessarily go on to develop an allergic disorder.

© Getty

Did you know?
Sharks have been on Earth longer than trees

How does a shark navigate?

Nadine Marie Stirmey

Sharks have a special sense that enables them to home in on small electric signals generated by prey. But the special electroreceptors in their skin also appear to be important in the long transoceanic migrations made by some species. The receptors develop small electrical currents in response to temperature gradients, and this may help those species that follow warm water currents. They are also sensitive enough to measure voltage gradients, electrical signals produced by the movement of oceanic water through Earth's magnetic field, as well as those generated by the shark's movements through that field. It's thought that this allows sharks to navigate as if they had their own magnetic compass.

WHY DO TORTOISES LIVE SO LONG?

Andy Mayer

Some animals live a very fast, dangerous, exciting life and put a lot of time and effort into having lots of offspring while they're still young; others, such as tortoises, have a much slower pace of life and use their resources to live longer. In comparison, they have much slower biological activities than a lot of other animals. Some believe that having a lower metabolic rate combined with an almost-complete 'switching off' during dormant periods of hibernation and aestivation plays a significant role in their living a long life.

Tortoises are equipped with adaptations allowing for their protection from predators. Once they reach a certain growth threshold, their shell gives them a fair amount of protection. Their predators are few, with perhaps humans being one of their most feared, certainly in the past. Living on an island where there is plenty of vegetation and where you'd be hard-pressed to find any other animal larger than yourself would also mean that you can be free to roam without fear of attack. Another biological feature that some feel may contribute to tortoise longevity is their very long telomeres – the protein caps at the ends of chromosomes. The theory is that telomeres shorten each time cells replicate, eventually becoming so stubby that they lead to the death of that cell. In this way, the telomeres act as an initial signal of cell health.

DOES A USB STICK OR SD CARD STORE ANY DATA FROM ITEMS THAT HAVE BEEN ERASED?

Clare Leahy

There's a common misconception that once data is deleted from a USB stick, SD card or even your computer's hard disk, it's gone forever. When something is deleted, either from your hard drive or a USB flash stick or secure digital (SD) card, it's unlikely that the file has been erased. What is usually erased is the pathway, or link, which your computer uses to identify the location of the particular file. There are many software recovery solutions which enable you to bring files 'back from the dead'. Most files are stored as a series of zeroes and ones, and although sometimes parts of files can become corrupted or disappear forever, the chances are that if you hit delete by accident, it's not necessarily time to panic just yet.

WHY DO THE BULBS IN MY GARDEN GROW IN DIFFERENT COLOURS EACH YEAR?

Robert Smith

They are almost certainly not the same plants. While some plants – hydrangeas, for example – may well change flower colour when grown in soils of different acidity levels, it's unlikely that the soil conditions will have changed markedly around a bulb from one year to the next. Very rarely a genetic mutation might occur that could result in the loss of a particular pigment, changing flower colour, but it is much more likely that seedlings or other previously non-flowering bulbs have come up in more or less the same spot.

Who arranged the periodic table, and when?

Matt Lathan

The periodic table shows all the chemical elements which make up matter in an ordered and useful way. The current recognisable form began with a Russian scientist called Dmitri Mendeleev in 1869. Mendeleev was a Russian chemist and inventor, and he was able to use the periodic table that he had created to successfully predict elements which had not then been discovered. Since then, many more elements have been predicted and discovered, totalling 118 at present. Mendeleev was also famous for marrying a woman while he was still married to someone else and for standardising the amount of alcohol in Russian vodka at 40 per cent. Element 107, mendelevium, as well as the crater Mendeleev on the Moon, are named after him.

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THE LIBRARY

The latest book releases for curious minds

HOW THE VICTORIANS TOOK US TO THE MOON

Iwan Rhys Morus
HOW THE VICTORIANS TOOK US TO THE MOON
The Story of the Nineteenth-Century Innovators Who Forged the Future

THE MOVERS AND SHAKERS WHO SHAPED THE SPACE RACE OVER 100 YEARS AGO

AUTHOR **IWAN RHYS MORUS**
PUBLISHER **ICON BOOKS**
PRICE **£25 / $29.95**
RELEASE **OUT NOW**

There's a little surprise at the start of this book – a device that writers would call a 'twist' if it was a work of fiction. Author Iwan Rhys Morus sets the reader up believing one thing before there's an eye-opening 'reveal' that will take them by surprise, even if they had suspicions that the author was deceiving them in some way. No spoilers here, but it's convincing in its detail and pleasing in execution, setting the stage for an especially riveting science history read.

In case you were thinking that *How the Victorians Took Us to the Moon* is a book about some kind of secret project or technology that forward-thinking Victorian scientists had, it's not. It's a book about the technological and, just as importantly, cultural advancements of the Victorian era that allowed scientists to lay the foundations of the Space Race and, ultimately, the Apollo missions. Each chapter focuses on a different facet of the rudiments of space travel, and not just the obvious checkpoints that led to the Saturn V rocket. We're taken through the politics of the Royal Society, which promotes scientific advancement, at a time when the scientists were trying to separate themselves from the politicians and people who would use the Royal Society purely for political gain.

We learn about the visionary architect Isambard Kingdom Brunel and engineer George Stephenson as examples of what mid-19th century scientists and inventors aspired to achieve, how the first submarine cable was laid across the Atlantic from Britain to the US and

"Each chapter focuses on a different facet of the rudiments of space travel"

the internationally renowned exhibitions that were examples of the pride Victorians took in being people of science. There are also chapters covering the early development of electricity, telecommunications and flight.

The detail of *How the Victorians Took Us to the Moon* is truly fascinating. Morus gives a deep insight into Victorian subcultures we never knew existed and the direction that the scientific winds were blowing across 70 years of history. It comes as no real surprise that the author is a professor of history at Aberystwyth University, a fellow of the Royal Historical Society and that this isn't his first published history book. What does surprise us is just how compelling a read this is, though. It's not a book for most teenagers, but anyone with an interest in the history of science and space travel – or the Victorians, for that matter – should pick up *How the Victorians Took Us to the Moon*.

OUR TIME ON EARTH

ANIMAL LIFE SPANS, FROM THE MAYFLY TO THE IMMORTAL JELLYFISH

AUTHOR **LILY MURRAY**
ILLUSTRATOR **JESSE HODGSON**
PUBLISHER **TEMPLAR**
PRICE **£15.99 (APPROX. $13.95)**
RELEASE **OUT NOW**

Did you know honey bees only live for up to seven weeks and lobsters have a life span of over 100 years? You might be surprised by some of the animal ages in *Our Time on Earth*. As a concept, a book about how long it takes animals to die might sound a bit macabre, but nothing could be further from the truth. In a celebration of wildlife, Lily Murray reveals the interesting lives of each animal, be it short or long, highlighting some fascinating behaviours and their importance to the wider ecosystem. There's plenty to discover here, such as the eternal life span of the immortal jellyfish or the 500-year-old sharks swimming around Greenland, thousands of metres below the surface. Along with wonderfully written content, it's worth purchasing *Our Time on Earth* for the illustrations alone. Each vibrant page brings the stories of the animals to life and will undoubtedly entice your little one to turn the page and see what's next.

THE ASTRONAUT'S GUIDE TO LEAVING THE PLANET

EVERYTHING YOU NEED TO KNOW, FROM TRAINING TO RE-ENTRY

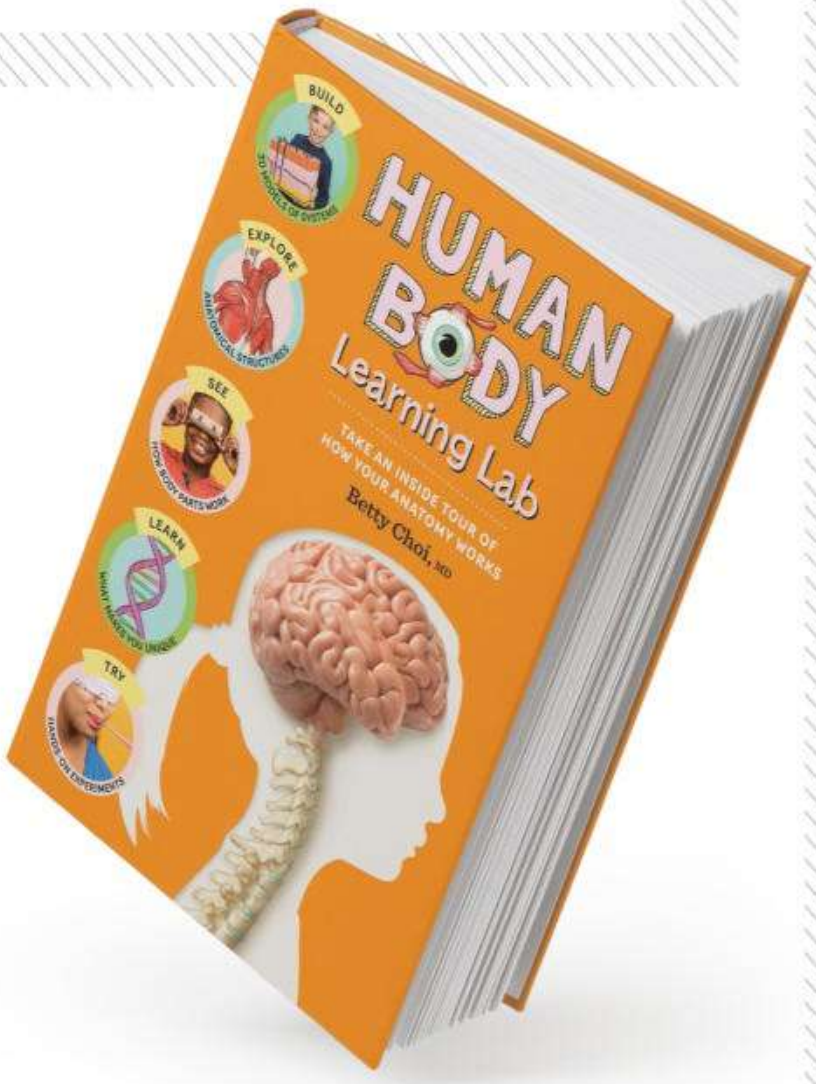
AUTHOR **TERRY VIRTS**
PUBLISHER **WORKMAN PUBLISHING COMPANY**
PRICE **£13.17 / $14.99**
RELEASE **25 APRIL**

NASA astronaut Terry Virts gives you the lowdown on all things spaceflight in this fantastic biographical guide for children. From his early ambitions of being an astronaut to launching into space and boarding the International Space Station, Virts takes his young audience on journeys few have made. Each page of *The Astronaut's Guide to Leaving the Planet* is not only populated with practical information about how to become an astronaut and what to expect in space, but also Virts' passion for spaceflight and attitude towards being an astronaut. Virts also dedicates entire pages to answering interesting spaceflight questions, such as how to use the bathroom in space and what time zone astronauts use. Full of firsthand accounts of experiences you won't read about in any textbook, along with fun experiments and activities to do at home, there's no doubt *The Astronaut's Guide to Leaving the Planet* will inspire the next generation of spacefarers.

HUMAN BODY LEARNING LAB

TOUR THE HUMAN BODY AND DISCOVER HOW YOUR ANATOMY WORKS

AUTHOR **BETTY CHOI**
PUBLISHER **STOREY PUBLISHING**
PRICE **£14.99 / $18.99**
RELEASE **OUT NOW**



From surface level, exploring the biology of your skin, to the cellular make-up of every system in your complex body, this book is your guide to everything about you. Inspired by the curious questions of the children she treats, author and paediatrician Betty Choi is equipped with the expert knowledge and experience of interacting with young minds needed to write this detailed guide.

What gives *Human Body Learning Lab* the power to inspire children is that the body's incredibly complex abilities are not overly simplified for a young mind. Instead, Choi uses conversational tone and thought processes young children will understand in order to explain the stages of our bodies' most astounding events. With each cell, organ and biological reaction, clear and colourful diagrams are included to enable the reader to visualise exactly what and why events are occurring. As well as including a large range of biological functions, the diagrams represent diversity in skin colour, ages and body types. As the title suggests, this is not just a book, but a resource to learn through activities. Readers are instructed on how to make their own DNA, cell and ear models, as well as take part in educational games such as reflex and scent tests.

PLANETS

BLAST OFF ON A TOUR AROUND OUR SOLAR SYSTEM

AUTHOR **JOHN DEVOLLE**
PUBLISHER **PUSHKIN CHILDREN'S BOOKS**
PRICE **£12.99 / $16.95**
RELEASE **OUT NOW**

Filled with quirky illustrations and incredible facts about the Solar System, *Planets* takes the reader on an introductory tour of the planets. And by the end it becomes very clear why Earth is the best place for us to be – as well as what the environments are like on the seven other worlds in the Solar System. The existence of life on our planet is remarkable, but how do conditions change when you travel closer to the Sun, or if we experienced as much volcanic activity as Venus?

Author and illustrator John Devolle has chosen imagery, jokes and facts about each location in the Solar System that will most entertain and intrigue a young reader. For example, what would eating spaghetti bolognese look like on Mars? And how long would it take to reach your first birthday on Neptune compared to on Earth? For a short read, this book fits in the essential and most mesmerising Solar System details for children around five years old. The next time you're sitting at home feeling bored, you can remember just how fast you are hurtling around the Sun at all times!

BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

7	8	6					2	9
1	9	5	2	7		6	3	4
		4		5	9	8	1	7
2	4					7		
8		7	4		1	3		2
			8		7			
9		1	7					8
6			9	3		1		
4				8				

MEDIUM

				7		4		3
7		1	4			8		
	6			9				2
		6			7			5
9			3	1	5			
3	2			6		1	9	
5	9			8		6		
8	4	7						
		3	2			7	5	

HARD

2		8	4					
1					5		6	
					8			
		7			4			
	5				6	3		
				7		8		4
	2					9	4	
			7		1			
3		4	8	2		1	5	

Word search

Find the following words

INTELLIGENCE
ICEBERG
PENTAGON
PASTEUR
BREATHE
HURRICANE
KETCHUP
WIND
ROBOT
HEATING
HELMET
SEGWAY

H	E	L	F	R	O	B	O	T	O	S	E	G	W	I
U	M	T	P	A	S	T	A	L	B	E	K	O	S	N
R	I	C	E	B	E	R	G	A	C	H	N	T	E	T
B	R	E	N	A	K	E	T	H	O	L	D	J	F	E
I	E	Q	T	R	H	E	L	M	E	T	E	S	O	L
Y	C	K	A	P	A	Z	D	U	P	H	U	I	V	L
A	S	B	G	V	E	N	M	K	T	E	O	N	P	I
W	J	A	O	C	B	Y	D	A	R	A	U	P	X	G
G	W	I	N	D	O	V	E	F	K	T	E	U	T	E
E	I	N	T	E	L	R	G	E	N	I	O	H	L	N
S	B	U	W	Y	B	C	O	P	E	N	I	C	J	C
D	E	S	T	O	S	E	G	W	A	G	E	T	U	E
M	Q	P	A	S	T	E	U	R	L	Y	S	E	O	L
Y	E	N	R	T	W	I	T	C	K	E	A	K	L	P
A	H	U	R	R	I	C	A	N	E	O	B	E	B	N

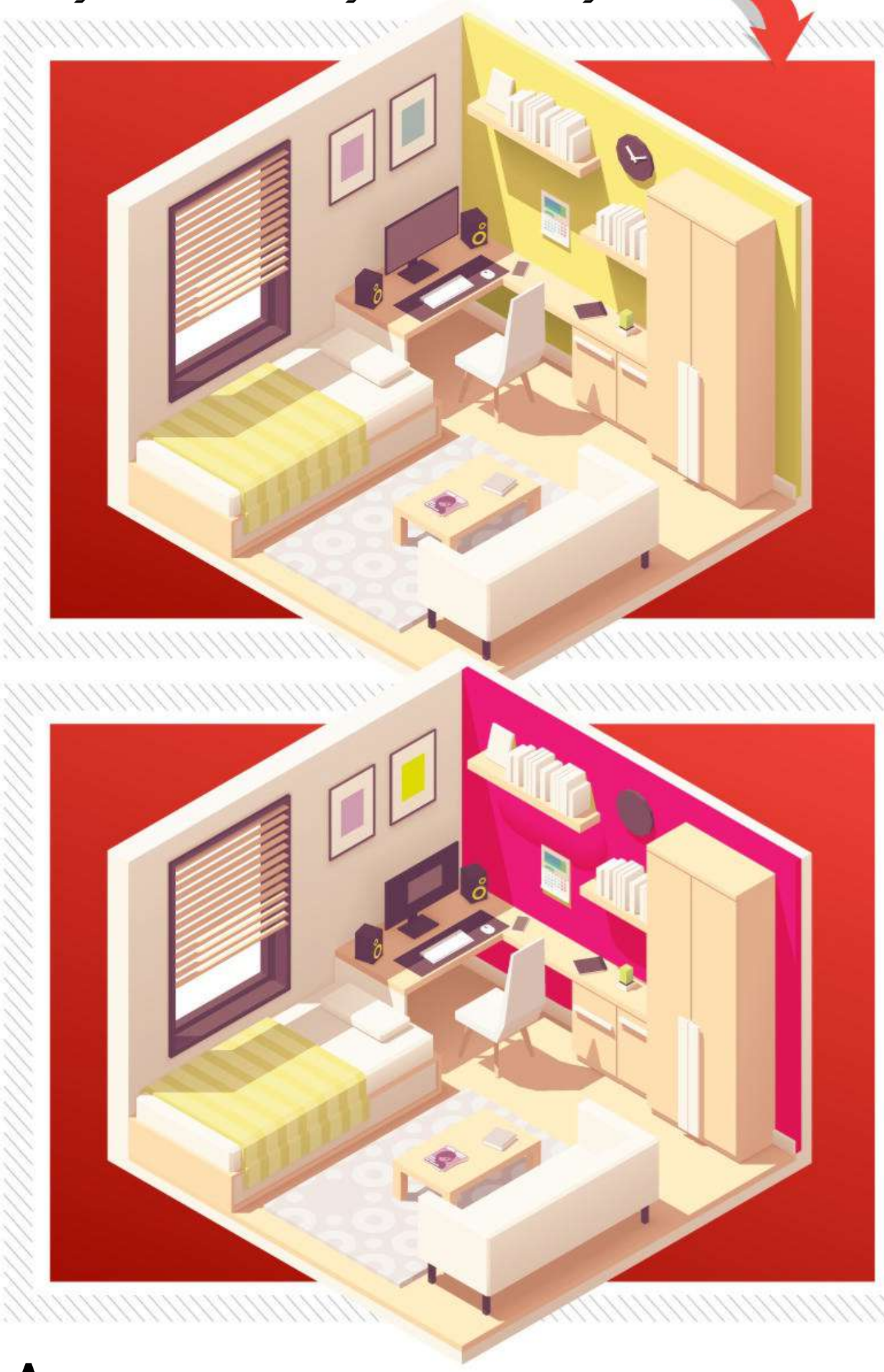
What is it?

Hint: Ground for a hot drink

A

Spot the difference

See if you can find all six changes between the images below



Answers

Find the solutions to last issue's puzzle pages

Q1 1.0 TO 2.0
Q2 THE OCEAN
Q3 DIAMONDS
Q4 90 PER CENT
Q5 208 DAYS
Q6 $50,000

What is it?

COAL

Spot the difference

QUICKFIRE QUESTIONS

Q1 Who is known as the 'father of medicine'?

- Hipparchus
- Da Vinci
- Hippocrates
- Socrates

Q2 Which planet has the most moons, with 83?

- Jupiter
- Neptune
- Uranus
- Saturn

Q3 Scurvy is a disease caused by a lack of vitamin:

- A
- B
- C
- D

Q4 Where was King Tutankhamun buried?

- Dale of the Dead
- Tomb of the Pharaohs
- Realm of the Monarchs
- Valley of the Kings

Q5 Where is the smallest bone in your body found?

- Nose
- Ear
- Hand
- Mouth

Q6 Approximately how many earthquakes occur annually?

- 20
- 200
- 2,000
- 20,000

© Getty

HOW TO...

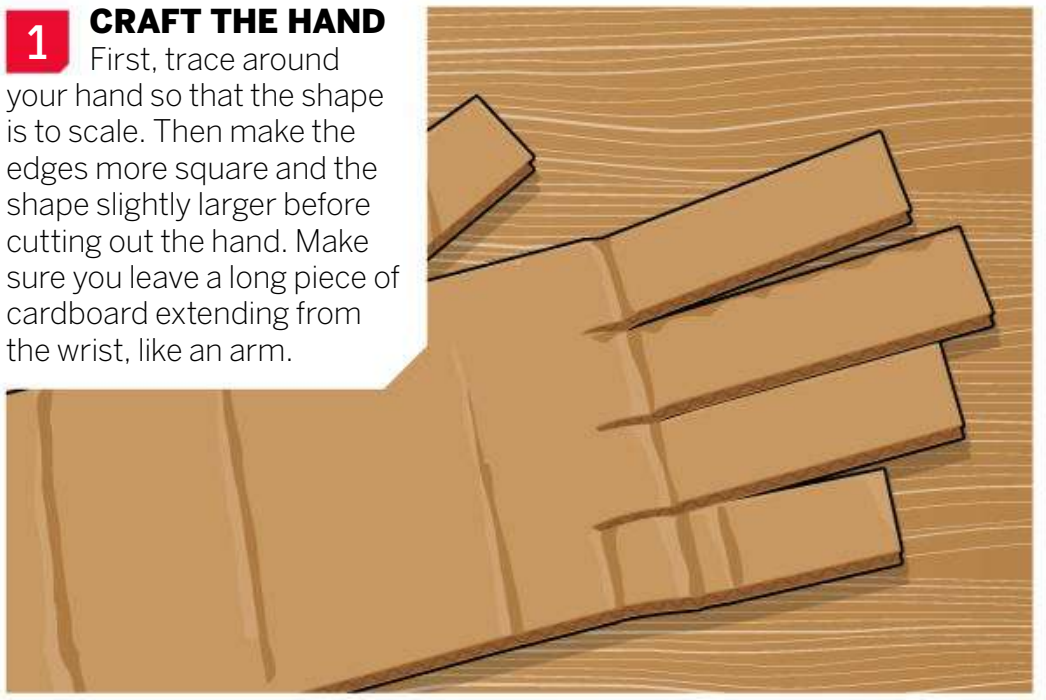
Practical projects to try at home

MAKE A ROBOTIC ARM

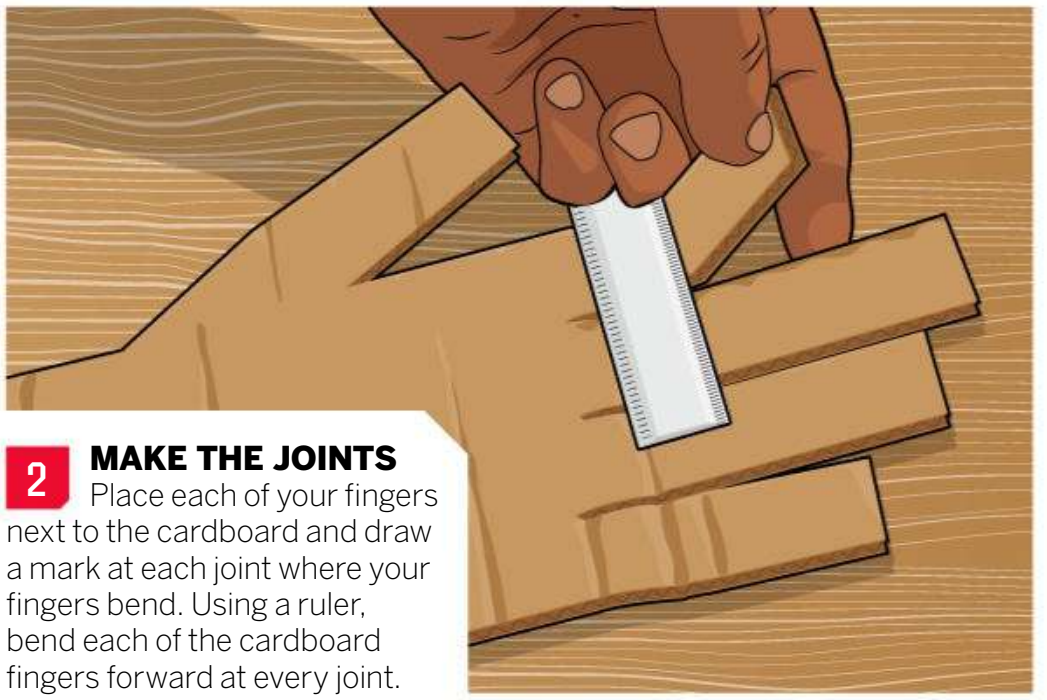
What will you pick up with your homemade mechanical arm?

KIT LIST

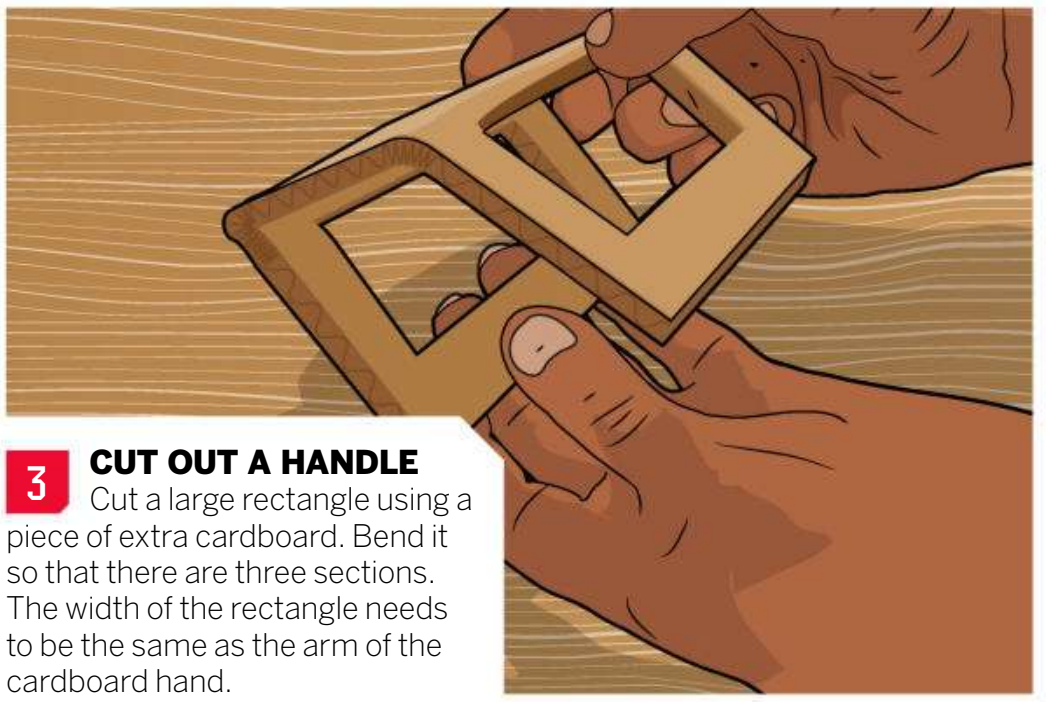
- A large piece of cardboard
- Ruler
- Scissors
- Five plastic straws
- Strong glue
- String



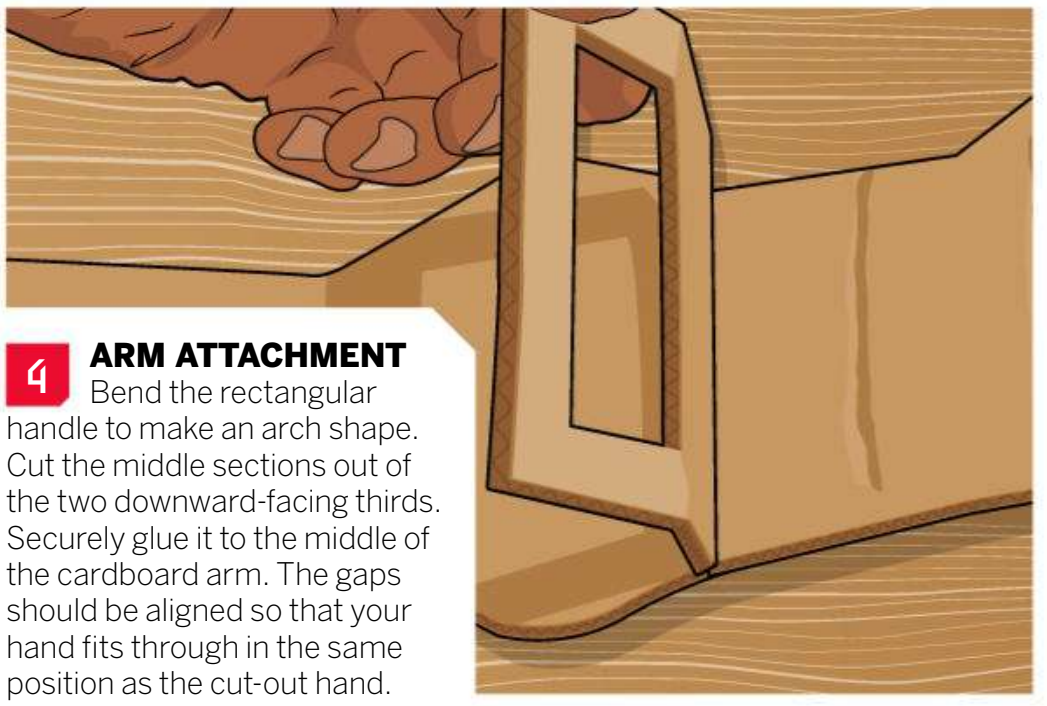
1 CRAFT THE HAND
First, trace around your hand so that the shape is to scale. Then make the edges more square and the shape slightly larger before cutting out the hand. Make sure you leave a long piece of cardboard extending from the wrist, like an arm.



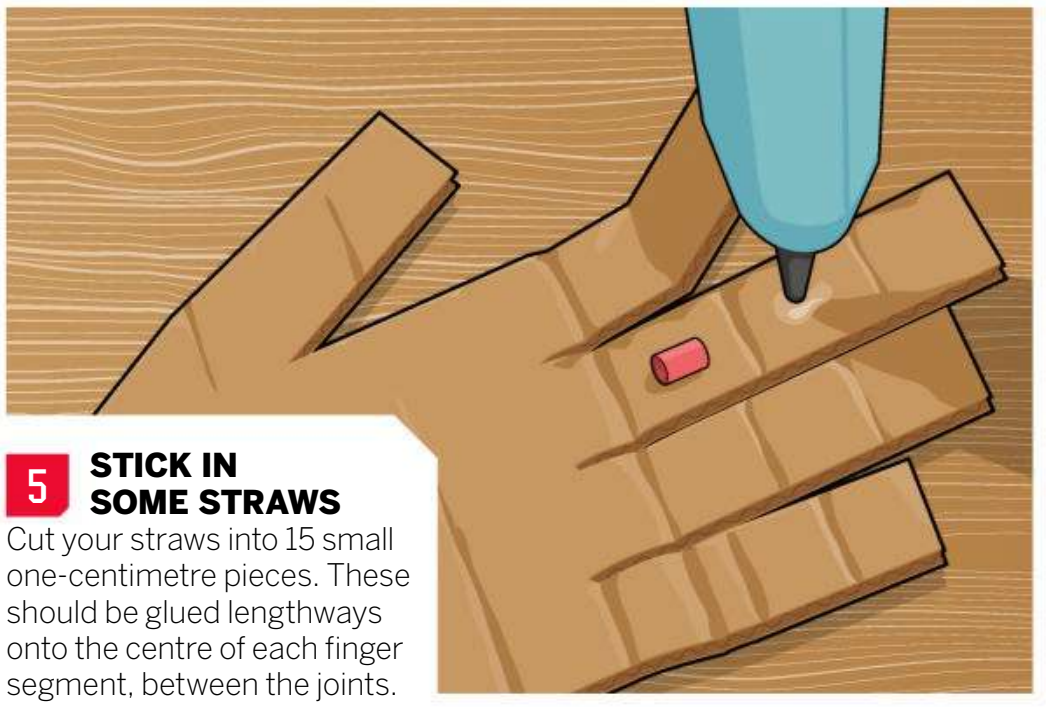
2 MAKE THE JOINTS
Place each of your fingers next to the cardboard and draw a mark at each joint where your fingers bend. Using a ruler, bend each of the cardboard fingers forward at every joint.



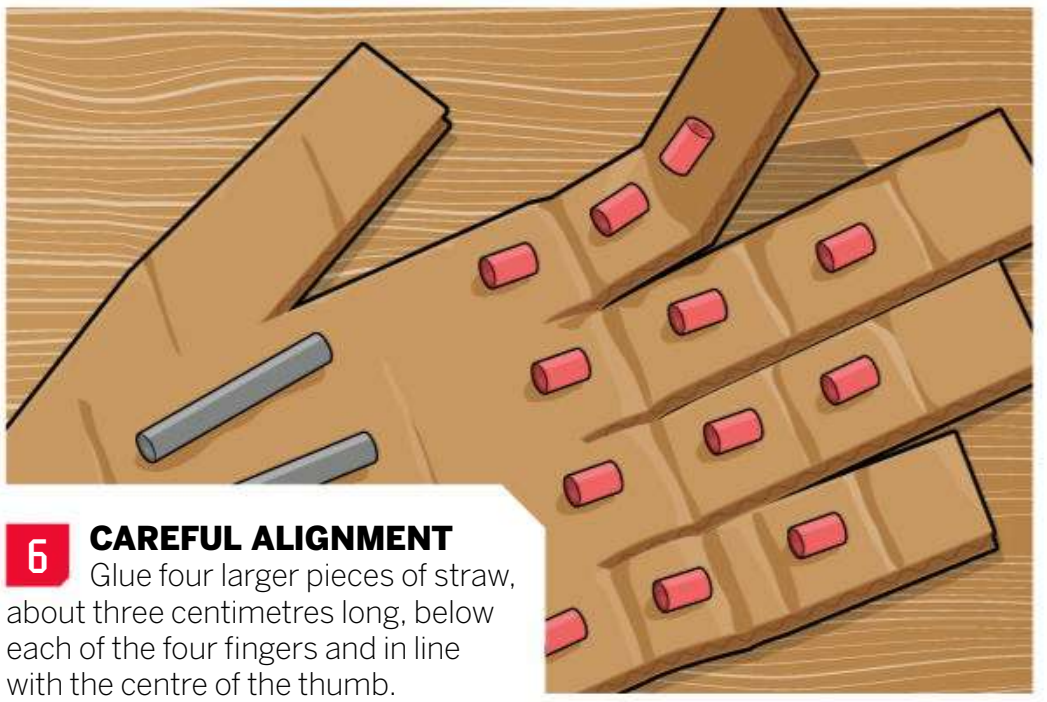
3 CUT OUT A HANDLE
Cut a large rectangle using a piece of extra cardboard. Bend it so that there are three sections. The width of the rectangle needs to be the same as the arm of the cardboard hand.



4 ARM ATTACHMENT
Bend the rectangular handle to make an arch shape. Cut the middle sections out of the two downward-facing thirds. Securely glue it to the middle of the cardboard arm. The gaps should be aligned so that your hand fits through in the same position as the cut-out hand.



5 STICK IN SOME STRAWS
Cut your straws into 15 small one-centimetre pieces. These should be glued lengthways onto the centre of each finger segment, between the joints.

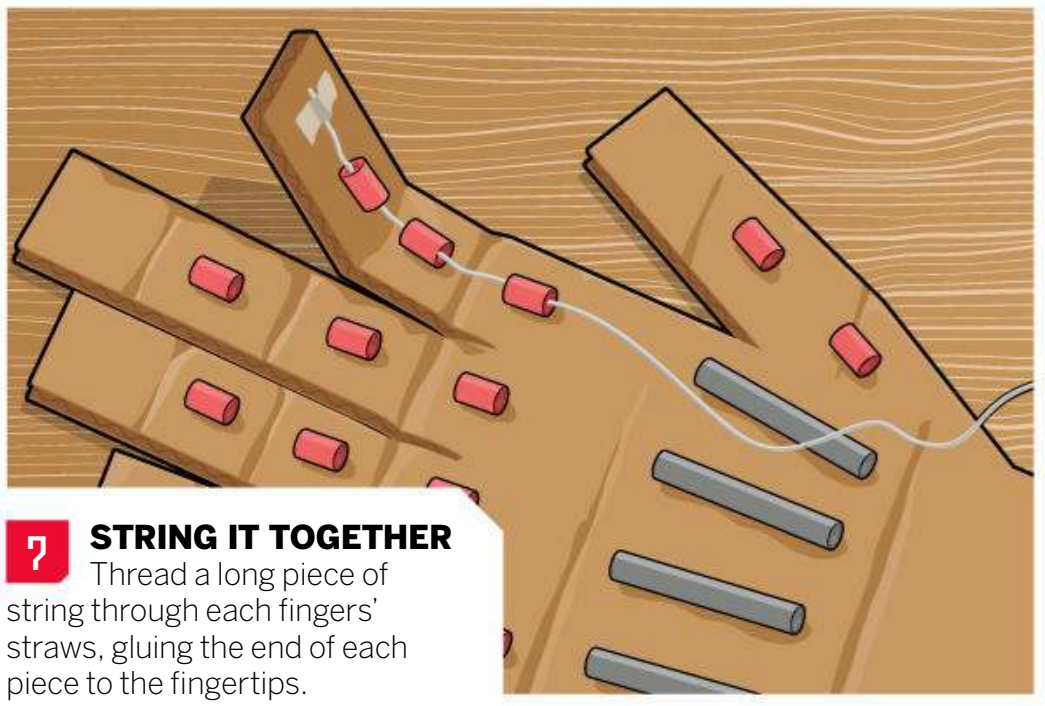


6 CAREFUL ALIGNMENT
Glue four larger pieces of straw, about three centimetres long, below each of the four fingers and in line with the centre of the thumb.

NEXT ISSUE
MAKE YOUR OWN HOLOGRAM

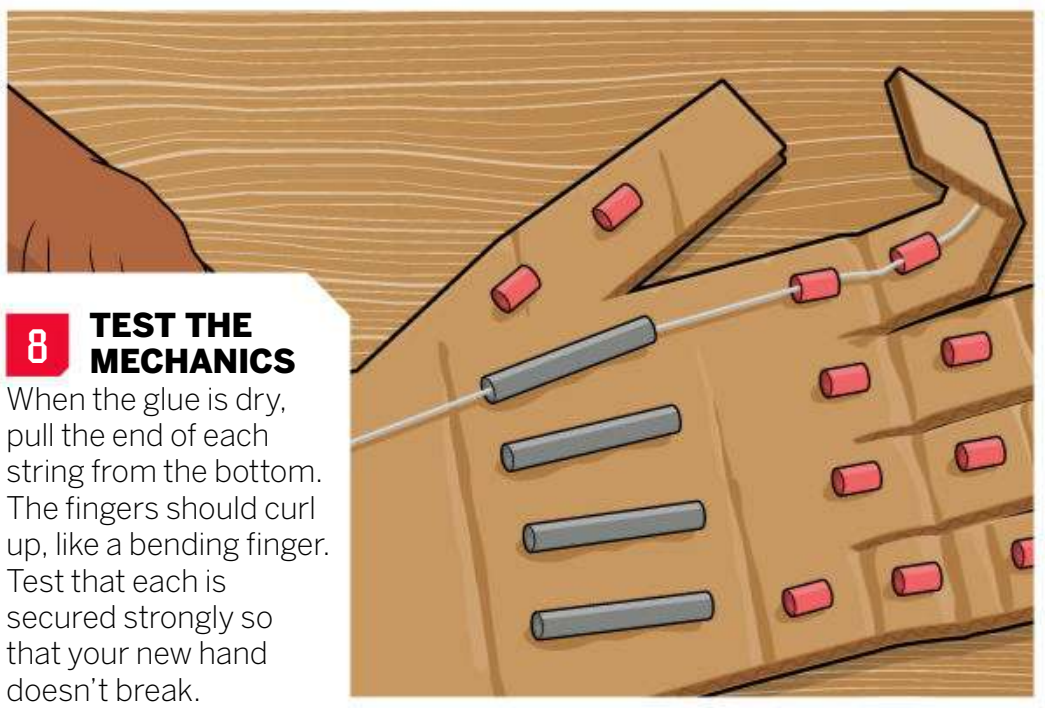
DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you



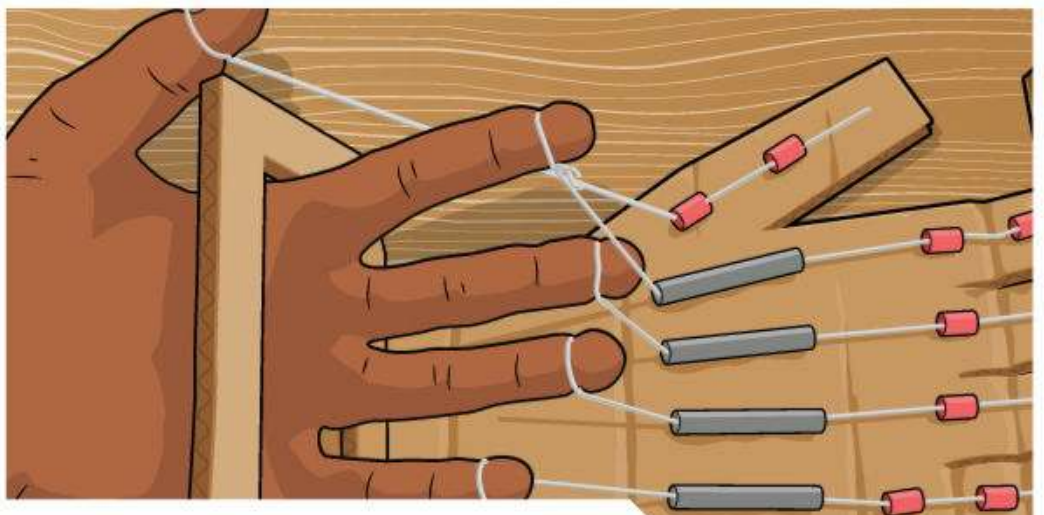
7 STRING IT TOGETHER

Thread a long piece of string through each fingers' straws, gluing the end of each piece to the fingertips.



8 TEST THE MECHANICS

When the glue is dry, pull the end of each string from the bottom. The fingers should curl up, like a bending finger. Test that each is secured strongly so that your new hand doesn't break.



9 HAND IN HAND

Poke your hand through the cardboard hand and tie the loose ends of string to the tips of each corresponding finger. The strings should be straight when your hand is flat.

10 GRAB YOURSELF A DRINK

...or anything you want. Now that your hand's movements are connected to your robotic arm's, practise using your extended hand to pick up different objects.

SUMMARY

The human hand is a complex limb to imitate. It has 27 bones, 27 joints, 34 muscles and more than 100 ligaments and tendons to give it dexterity. While some intricate robotic arms have been designed to mimic almost every precise angle and range of movement of the human hand, this simple creation gives you enough control to play with many of the objects around you. To give the robotic arm more accurate control over the thumb, the string should be threaded through a hole to the back of the hand instead of through a final long straw piece like the fingers.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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INBOX

Speak your mind

Members of wildlife services analysed the bodies of the stranded whales

TASMANIA TRAGEDY

Dear **HIW**,
There was recently a mass whale stranding in Australia. What phenomenon causes this? Could there be any correlation to recent earthquakes in the Asia-Pacific region?
Rowan MacDonald

In September, around 230 pilot whales washed up on a beach on the west coast of Tasmania. When they were found, around half were already dead. Pilot whales are so large, growing up to six metres long, that when out of the water their organs can be damaged under their own weight. Scientists aren't sure what brought so many of them to shore, but they do travel in large pods. Some think they were chasing prey such as squid, which can travel very close to the shore.

Tasmania is an island off the coast of Australia often referred to as a whale trap because beaching is relatively common there, likely due to the strong and fast-moving tides. When whales are hunting they can lose track of changing tides, causing them to become stranded. Whales also have strong social bonds, meaning some whales will hear the distress calls of other pod members and might attempt to help. Your comment about the recent earthquakes in the area is very interesting. Though there's no evidence to say this may have happened, it's true that earthquakes can alter the migration path of whales. At the time of an earthquake, the local magnetic field can become altered slightly. Some scientists say that whale migrations are driven by the animals detecting Earth's magnetic field, so when earthquakes change these, it could cause strandings.

LETTER of the MONTH

WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

THE ASTRONAUT'S GUIDE TO LEAVING THE PLANET

Former NASA astronaut Terry Virts guides readers through the practical elements of becoming an astronaut, along with the wonders and challenges of space travel

MICROPLASTIC REDUCTION

Dear **HIW**,
Issue 170 featured an article on the harm caused by microplastics, including Styrofoam. It's therefore disappointing that the How to project featured Styrofoam without any advice on how to safely dispose of the materials used in the project. The science is both important and interesting, but so is tidying up.
Ossie

Thank you for drawing our attention to this, Ossie. In issue 170 of How It Works we did make reference to the contribution of Styrofoam to microplastic accumulation, and you are right that knowing how to dispose of environmentally harmful materials is vital. Like many plastic products, the microplastics that result from Styrofoam can't be fully broken down. This means that the best way to dispose of a Styrofoam product is to search for a Styrofoam-recycling facility. Not many recycling facilities will recycle Styrofoam because it's difficult to clean and expensive to recycle, so make sure you check out specific facilities online.

Styrofoam is a popular packaging material, though it's harmful to the environment when it isn't disposed of properly

YOUR MOUTH MICROBIOME

Dear **HIW**,
In issue 168 you have an amazing picture of dental bacteria. You describe the bad effects of bacteria in the mouth. Surely we wouldn't have evolved with the bacteria unless they also served a useful purpose? Perhaps using antibacterial toothpaste to get rid of them may not be a wholly good idea?
Stephen

There are also many types of harmful bacteria that can enter the mouth, and the microbiome is all about balance. An unhealthy diet and a lack of oral hygiene can cause the balance to shift, with harmful bacteria taking over. Antibacterial toothpaste targets harmful bacteria, stopping it from sticking to your teeth.

Toothpaste usually contains antibacterial ingredients

NEXT ISSUE ISSUE 172 ON SALE 22 DEC 2022

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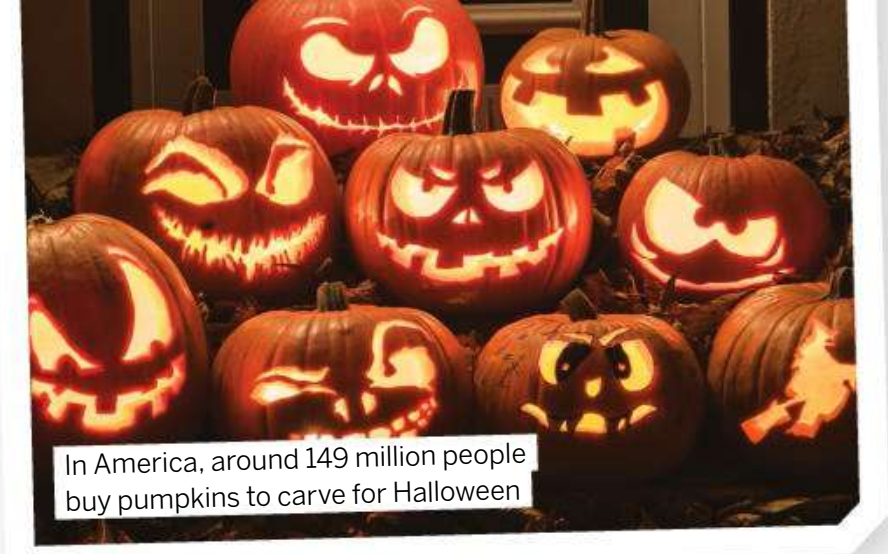

In America, around 149 million people buy pumpkins to carve for Halloween

HALLOWEEN HELP

Dear **HIW**,
Like many of my friends, I carved a pumpkin to put outside for Halloween. But I didn't know what to do with the insides. I wasted quite a lot of it this year – how can I reuse it?
Jordan Hicks

This is an important consideration to make during the Halloween period if you wish to help the environment, and one that only a small percentage, like yourself, make. The best way to reduce this food waste is to find other uses for its contents, such as cooking. Although it takes more time, you can remove and roast the seeds to eat and save the pumpkin scraps for soups, pies and vegetable stock. However, if you don't feel like eating the pumpkin, all of its leftovers can be composted in your garden or donated to a local farm as animal feed.

240 millilitres of orange juice contains 137 per cent of your RDI of vitamin C

JUICE NUTRITION

Dear **HIW**,
Which type of fruit juice has the most vitamin C in it? And what other vitamins are in high concentrations in fruit juice?
Amber Scarff

Orange juice and other citrus juices top the list when it comes to vitamin C content. But vegetable juice shouldn't be overlooked. Other juices high in vitamin C include green juices made with cabbage, broccoli and kiwi. In terms of other vitamins, each fruit juice will vary in concentrations of specific vitamins. As well as being a leading vitamin C source, one 240-millilitre glass of orange juice contains four per cent of your recommended daily intake (RDI) of vitamin A, 18 per cent of thiamine and seven per cent of vitamin B6.

WE ASKED YOU

This month on social media, we asked you: Which of the four seasons is your favourite?

@DARYA.7.7.1991
Spring because everything is refreshing and life is beginning again

@RAK.MALIGE
Spring, as the warmth is returning, days are longer and everything is becoming green

@JEANMCDOUGALL8333
Summer

@FATEMEH.JINYOUNG
Winter because of snow and rainfalls

@MABEVVO
Spring

@DOODLENEWS
As a photographer, I like autumn. The Sun stays lower in the sky compared to summer, which provides great lighting for the autumn colours

© Getty

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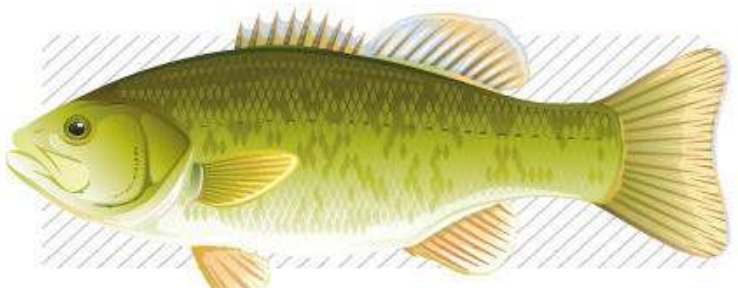
FAST FACTS

Amazing trivia that will blow your mind

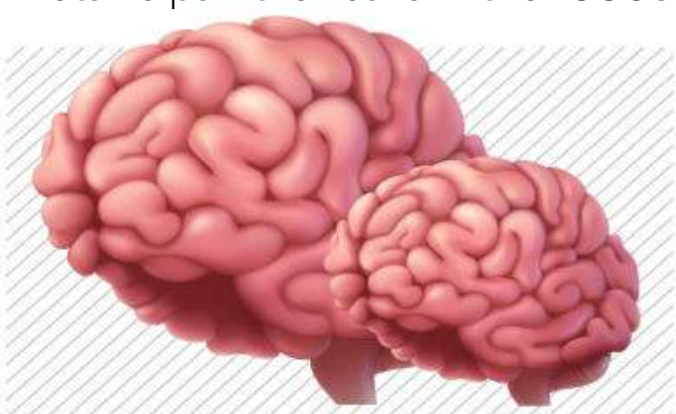
ONE IN SIX

One-sixth of Google searches have never been searched for before



40,000

The number of fish scales required to make a kilogram of metallic paint for cars in the 1930s



THE BRAINS OF FIRST-TIME FATHERS SHRINK

2.25 MILLION TONNES

A swarm of tiny krill can weigh 15,000 times more than a blue whale

1517

In this year, Leonardo da Vinci designed a walking mechanical lion

100x

Uranium is much more abundant on Earth than silver

250 MILLION BCE

Ancient Earth was purple, rather than green

50%

Half of all humans have mites living in their eyelashes

You always have room for dessert because your stomach expands on contact with sugar

THE BOOK ADAPTED INTO THE CLASSIC DISNEY FILM *BAMBI* WAS BANNED BY THE NAZIS

ONE DEGREE CELSIUS

Every degree of global warming results in a 12 per cent increase in lightning strikes

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